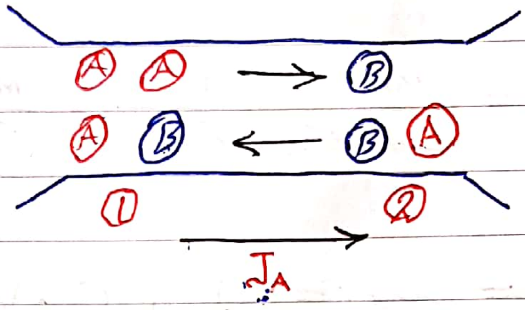
DATE / / OBJECT

منتظر صلاح حسين

Chapter one :- Diffusion

1- Fick's low of diffusion :-



$$C_{A_1} > C_{A_2}$$

$$\xleftarrow[J_B]{\qquad}$$

$$C_{B_2} > C_{B_1}$$

$$J_A \propto \frac{dC_A}{dz}$$

$$\boxed{J_A = -D_{AB}\frac{dC_A}{dz}} \quad \text{------} \quad (1)$$

J_A = is the molecular diffusion in $kmol/s.m^2$

C_A = is the contraction of A . $kmol/m^2$

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Diffusion with bluk in motion:-

Total D. = molecular D. + convection مصطلح term.

convection term = Eddy D. = molar توصف flux = $C_A \cdot V$

concentration ← velosity

$$V = \frac{N_A + N_B}{C_T} = \frac{\text{mass flux}}{\text{concentration}} = \frac{m}{s}$$

$$\therefore \text{Total D.} = N_A = J_A + C_A \cdot V$$

total flux, or total. D.

$$\boxed{N_A = -D_{AB}\frac{dC_A}{dZ} + \frac{C_A}{C_T}\left[N_A + N_B\right]} \quad \text{---- (2)}$$

* عند النقطة ① أكبر تركيز هو A وفي النقطة ② أكبر تركيز هو B

- في حالة التركيز في نقطه ① أكبر من (B) يكون

$C_{A_1} > C_{AB}$

ويكون (molar diffusion)

$$J_A = -J_B$$

$$D_{AB} = D_{BA}$$ (معدل الانتشارية)

With You Step By Step

Total D. for gas and liquid can be written two ~~the~~ term:-

① by pressure :- partial pressure

$$PV = nRT$$

$$P = \frac{n}{V} RT$$

$$P = C\,RT \quad \text{and} \quad P_T = C_T\,RT$$

$$P_A = C_A\,R.T \Rightarrow C_A = \frac{P_A}{RT}$$ نشتقها

② نعوضها في المعادلة $\boxed{dC_A = \frac{1}{RT}\,dP_A}$

$$N_A = -D_{AB}\frac{dP_A}{dZ.\,R.T} + \frac{P_A}{P_T}\left[N_A + N_B\right]$$

$$\boxed{N_A = \frac{-D_{AB}}{R.T}\cdot\frac{dP_A}{dZ} + \frac{P_A}{P_T}\left[N_A + N_B\right]} \quad \text{③}$$

② by mole fraction :-

$$x_A = \frac{P_A}{P_T} \quad , \quad x_A = \frac{C_A}{C_T}$$

$$\boxed{\therefore N_A = \frac{-D_{AB} \cdot P_T}{RT} \cdot \frac{dx_A}{dz} + x_A \left[N_A + N_B \right]} \quad \text{---- ③}$$

modes of Diffusion

موكرس ا.جواد

ساكن
متلاكتش
stagnant

$N_B = 0$

مثلاً يذكر في السؤال
غاز انتشر في البحر أو
في الهواء فتكون
$N_B = 0$

counter diffusion

equimolecular

$N_B = -N_A$

as Distillation

مثلا في حالات التقطير

unequimolecular

$N_B = -nN_A$

في التفاعلات الكيميائية

$A \longrightarrow \underline{\underline{3}} B$

stochimetric coefficient

D_{AB} = diffusion of A in B

d = derivative مشتقة

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1 Stagnent case :- $N_B = 0$

$$N_A = \frac{-D_{AB}}{RT} \cdot \frac{dP_A}{dz} + \frac{P_A}{P_T}\left[N_A\right] \quad \text{---- (1)}$$

$$\therefore N_A = \left[1 - \frac{P_A}{P_T}\right] = \frac{-D_{AB}}{RT} \cdot \frac{dP_A}{dz} \quad \text{---- (2)}$$

$$N_A = \frac{-D_{AB}}{R.T} \cdot \frac{1}{dz}\left(\frac{dP_A}{\left[1 - \frac{P_A}{P_T}\right]}\right) * \frac{P_T}{P_T} \quad \text{---- (3)}$$

$$\therefore N_A = \frac{-D_{AB}}{R.T} \cdot \frac{P_T}{dz} \int_{P_{A_1}}^{P_{A_2}} \left(\frac{dP_A}{P_T - P_A}\right)$$

by integration :-

$$\boxed{N_A = \frac{D_{AB}}{R.T} \cdot \frac{P_T}{dz} \ln\left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}}\right]} \quad \text{---- (4)}$$

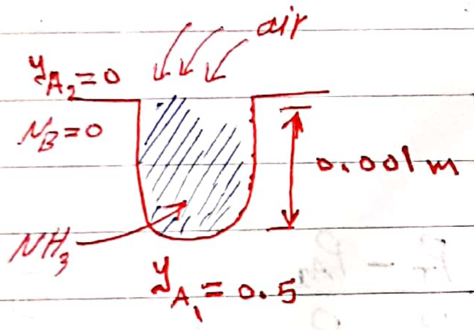
في حالة الركود ((stagnent))

EX) Ammonia gas is diffusion at a constant rate through a layer of stagnent air (1 mm) thickness. conditions are such that the gas content 50 percent by volume ammonia at one boundary of the stagnent layer. The Tempature is 295 K and the pressure atmosphere 101.3 Kpa under these condition the diffusivity of (NH_3) in air is 0.18 cm^2/sec. estimate the rate of diffusion of (NH_3) through the layer?

(مهم)

Sol)

$T = 295\ K$, $D_{AB} = 0.18\ cm^2/s$



$$N_A = \frac{D_{AB}}{R \cdot T} \cdot \frac{P_T}{dZ} \left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}} \right]$$

$P_T = 101.3\ Kpa$, $\underset{(air)}{P_{A_2}} = 0$, $\underset{(NH_3)}{P_{A_1}} = \underset{(NH_3)}{y_{A_1}} \cdot P_T$

$P_{A_1} = 0.5 \times 101.3 = 50.65\ Kpa$

$dZ = 0.001\ m$

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$$N_A = \frac{1.8\times10^{-5}}{8.314\times295} \cdot \frac{101.3}{1\times10^{-3}} \ln\left[\frac{101.3-0}{101.3-50.65}\right]$$

$$= 5.153\times10^{-4} \ Kmole/s.m^2$$

⊛ في حالة طلب معدل الانتشار بوحدات (Kmol/s) نقوم باستخراج المساحة ونضربها في (N_A) فيصبح القانون

$$\boxed{\bar{N}_A = N_A \cdot A}$$

2 counter diffusion:-

ⓐ equimolecular counter diffusion:-

$$N_A = \frac{-D_{AB}}{R.T} \cdot \frac{dP_A}{dz} + \frac{P_A}{P_T}\left[N_A + N_B\right] \quad --- ①$$

$N_B = -N_A$ sub in — ①

$$\therefore N_A = \frac{-D_{AB}}{R.T} \cdot \frac{dP_A}{dz}$$

$$\therefore \boxed{N_A = \frac{-D_{AB}}{R.T} \cdot \frac{dP_{A_2} - dP_{A_1}}{\cancel{d}(z_2 - z_1)}}$$

for equimolecular counter diffusion

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Ex) In an air- carbon dioxide mixture at 298 K and 202.5 Kpa the concenteration of CO_2 at Two planes (3mm) apart are 15% vol. and 25% vol the diffusity in air at 298 K is $8.2*10^{-6}$ m²/s. calculate the rate of diffusion assuming
@ equimolecular counter diffusion.
ⓑ stagnent layer of air.

Soll) @

$$P_{A_1} = y_{A_1} \, P_T = 0.15 \times 20\cancel{2}.6 = 30.29 \text{ Kpa}$$

$$P_{A_2} = y_{A_2} \, P_T = 0.25 \times 202.6 = 50.65 \text{ Kpa}$$

$$\therefore N_A = \frac{-D_{AB}}{R.T} \cdot \frac{dP_A}{dZ}$$

$$N_A = \frac{-8.2 \times 10^{-6}}{8.314 \times 298} \cdot \left[\frac{50.65 - 30.29}{3 \times 10^{-3}} \right]$$

$$= 2.23 \times 10^{-6} \text{ Kmol/s.m}^2$$

(b)

$$N_A = \frac{D_{AB}}{R.T} \cdot \frac{P_T}{dZ} \ln\left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}}\right]$$

$$= \frac{8.2\times10^{-6}}{8.314\times298} \times \frac{202.6}{3\times10^{-3}} \times \ln\left[\frac{202.6-30.39}{202.6-50.65}\right]$$

$$= 2.79\times10^{-5} \text{ Kmol/s.m}^2$$

(b) un equimoleculer counter Diffusion :-

(U.M.D) :-

$$N_B = -n N_A$$

$$\therefore \boxed{N_A = \frac{+D_{AB}}{R.T} \cdot \frac{P_T}{dZ} \cdot \frac{1}{(1-n)} \ln\left[\frac{P_T-(1-n)P_{A_2}}{P_T-(1-n)P_{A_1}}\right]}$$

Ex) Species A in a gaseous mixture diffuses through a (3 mm) thick film and reaches a catalyst surface where the reaction $A \longrightarrow 3B$ takes place. If the partial paressure of A in the bulk of the gas is $8.5\ KN/m^2$ and the diffusivity of A is $2\times10^{-5}\ m^2/s$. Find the mole flux of A. given the pressure and temp. of the system are 101.3 Kpa and 297 K, respectively.

Sol)

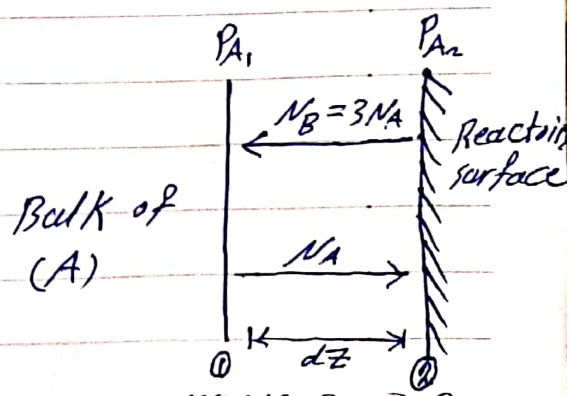
$$A \longrightarrow 3B \qquad \therefore A = 3$$

$$N_B = 3N_A$$

$$N_A = \frac{D_{AB}}{R.T} \cdot \frac{P_T}{\Delta Z} \cdot \frac{1}{(1-n)} \ln\left[\frac{P_T - (1-n)P_{A_2}}{P_T - (1-n)P_{A_1}}\right]$$

$$N_A = \frac{2\times10^{-5}}{8.314\times297} \times \frac{101.3}{3\times10^{-3}} \cdot \frac{1}{(1-3)} \ln\left[\frac{101.3+2(0)}{101.3+2(8.5)}\right]$$

$$= 2.12\times10^{-5}\ Kmol/m^2 * s$$



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Drift factor عامل الانجراف

note: for stagnent diffusion $\boxed{N_B = 0}$

$$N_A = \frac{D_{AB}}{R \cdot T} \cdot \frac{P_T}{dZ} \left[\frac{(P_T - P_{A_2}) - (P_T - P_{A_1})}{(P_T - P_{A_2}) - (P_T - P_{A_1})}\right] \cdot \ln \frac{P_T - P_{A_2}}{P_T - P_{A_1}} \quad (1)$$

from Dalton's law $(P_{Tot} = P_A + P_B)$.

and the deffinition of P_{Bm} = logarthmic mean of (P_{B_1} and P_{B_2})

$$P_{Bm} = \frac{(\cancel{P_T} - P_{A_2}) - (\cancel{P_T} - P_{A_1})}{\ln\left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}}\right]} = \frac{P_{B_2} - P_{B_1}}{\ln \frac{P_{B_2}}{P_{B_1}}} = P_{BM}$$

$$\therefore \boxed{P_{Bm} = \frac{P_{B_2} - P_{B_1}}{\ln \frac{P_{B_2}}{P_{B_1}}}} \quad \text{---- } (2)$$

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sub eq (2) in eq (1)

$$\boxed{N_A = \frac{D_{AB}}{R \cdot T} \cdot \frac{P_T}{dZ \cdot P_{BM}} \left(P_{A_1} - P_{A_2} \right)}$$ ⊛

$\frac{P_T}{P_{BM}}$ = drift factor

$\frac{P_T}{P_{BM}} = 1$ في حالات خاصة

* في بعض الحالات يساوي واحد اذا كان الفرق في الكسر المولي ليس كبيراً أي يبقى ثابت عندها فيكون

$D.f = 1$

Q) prove that for equimolecular counter diffusion that $D_{AB} = D_{BA}$

sol)

for (E.M.D) = $N_T = N_A + N_B = 0$

$$\therefore N_A = -N_B$$

$$J_A = -J_B \quad \text{---} (1)$$

$$N_A = J_A = -D_{AB}\frac{dC_A}{dZ} \quad \text{---} (2)$$

$$N_B = J_B = -D_{BA}\frac{dC_B}{dZ} \quad \text{---} (3)$$

$$\therefore N_A = -N_B$$

$$-D_{AB} * \frac{dC_A}{dZ} = D_{BA}\frac{dC_B}{dZ} \quad \text{---} (4)$$

$$C_T = C_A + C_B \Rightarrow C_A + C_B = 0$$

$$dC_A + dC_B = 0$$

$$dC_A = -dC_B \quad \text{---} (5)$$

$$\therefore \cancel{-} D_{AB}\cancel{\frac{dC_A}{dZ}} = \cancel{-} D_{BA}\cancel{\frac{dC_A}{dZ}}$$

$$D_{AB} = D_{BA}$$

- maxweall's law for multicomponent

- If A diffuse through B, C, D ... etc.

Then.

$$\boxed{N_A = -D_{Am} \cdot C_T \frac{dx_A}{dZ} + x_A (N_A + N_B + N_C \ldots)}$$

where: D_{Am} = is the effective diffusivity of (A)

if $N_B = N_C = N_D = 0$ then in stagnent layer.

$$\boxed{\frac{1 - x_A}{D_{Am}} = \frac{x_B}{D_{AB}} + \frac{x_C}{D_{AC}} + \frac{x_D}{D_{AD}} \ldots}$$

and

$$\boxed{N_A = \frac{D_{Am}}{R.T} \cdot \frac{P_T}{dZ} \ln \left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}} \right]}$$

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EX) Nitrogen is diffusing under steady condition through a mixture of 2% N_2, 20% C_2H_2, 30% C_2H_4 and 48% C_4H_{10} at 298 K and 100 kpa. The partial pressure of of N_2 at two planes (1 mm) apart are 13.3 & 6.67 kpa, respectively. Calculate the rate of N_2 across the two planes, The diffusivity of N_2 through C_4H_{10}, C_2H_6 and C_2H_6 may be taken as 9.6×10^{-6} m^2/s, 14.8×10^{-6} m^2/s and 16.3×10^{-6} m^2/s, respectively.

Sol)

since stagnent diffusion.

$$N_A = \frac{D_{Am}}{R \cdot T} \cdot \frac{P_T}{dZ} \ln\left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}}\right]$$

$$\frac{1 - y_A}{D_{Am}} = \frac{y_B}{D_{AB}} + \frac{y_C}{D_{AC}} + \frac{y_D}{D_{AD}}$$

$$\frac{1 - 0.02}{D_{Am}} = \frac{0.48}{9.6\times10^{-6}} + \frac{0.2}{14.8\times10^{-6}} + \frac{0.3}{16.3\times10^{-6}}$$

$$D_{Am} = 1.22\times10^{-5} \ m^2/s$$

$$N_A = \frac{1.22\times10^{-5}}{8.314\times298} \times \frac{100}{0.001} \ln\left[\frac{100 - 6.67}{100 - 13.3}\right]$$

$$= 0.0492 \ Kmol/m^2.s$$

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⊛ prediction of diffusivities :- معادلة تجريبية

$$D_{AB} = \frac{1.013 \times 10^{-7}\, T^{1.75} \sqrt{\frac{1}{M_A} + \frac{1}{M_B}}}{P\left[\left(\sum_a V_i\right)^{1/3} + \left(\sum_b V_i\right)^{1/3}\right]^2}$$

M_A , M_B :- Molecular mass of A and B

V_{ia} , V_{ib} :- summation of special diffusion volume give in table p.16

2ω

EX) estimate the diffusivity of methanol in air at atm pressure and 25°C.

sol) Table: 8.5

	v_i	
C	16.5×1	$v = 16.50$
H	1.98×4	$v = 7.94$
O	5.48×1	$v = 5.48$

$$\sum_a v_i = 29.90$$

and $V_{air} = 20.1$

$$D_{AB\,\text{methanol-air}} = \frac{1.013 \times 10^{-7} \times 298^{1.75} \times \left(1/32 + 1/29\right)^{1/2}}{1.013\left((29.9)^{1/3} + (20.1)^{1/3}\right)^2}$$

$$= 16.2 \times 10^{-6}\ m^2/s$$

$$= 15.9 \times 10^{-6}\ m^2/s$$

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H.W) what is the diffusivity in 30C° and then change pressure 2 atm

$$D_{AB} \propto \frac{T^{1.75}}{P}$$

⊛

With You Step By Step

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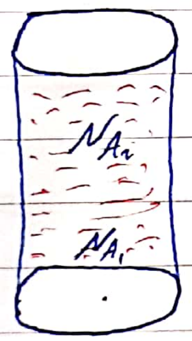
$\boxed{1.5}$ Diffusion through varying cross section area.

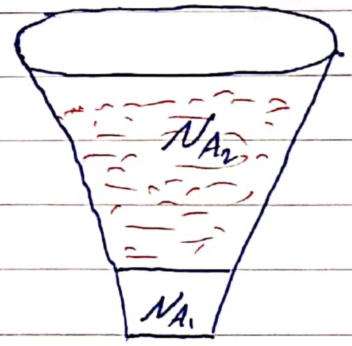
moler rate (Kmole/s) $= \bar{N}_A$

moler flux (Kmole/m^2.s)

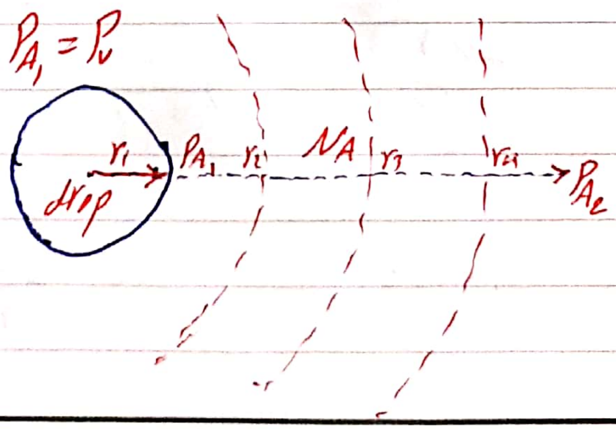
$$N_A = \frac{\text{mole rate}}{\text{surface area}} = \frac{\bar{N}_A}{A} = \frac{\text{Kmole}}{\text{s} \cdot \text{m}^2}$$



$N_{A_1} = N_{A_2}$



$N_{A_1} > N_{A_2}$



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$$N_A = -D_{AB}\frac{dC_A}{dr} + \frac{C_A}{C_T}\left[N_A + N_B\right] \quad ---(1)$$

$$\frac{\bar{N}_A}{A} = -D_{AB}\frac{dC_A}{dr} + \frac{C_A}{C_T}\left[\bar{N}_A + \bar{N}_B\right] \quad ---(2)$$

$$\bar{N}_A = -D_{AB}\cdot A\frac{dC_A}{dr} + \frac{C_a}{C_T}\left[\frac{\bar{N}_A}{A} + \frac{\bar{N}_B}{A}\right] \quad ---(3)$$

$$A = 4\pi r^2$$

$$\therefore \boxed{\bar{N}_A = -4\pi r^2 D_{AB}\frac{dC_A}{dr} + \frac{C_A}{C_T}\left[\bar{N}_A + \bar{N}_B\right]} \quad ---(4)$$

r^{-2}

$\frac{-2r^{-1}}{-1}$ $\quad \frac{+2}{r}$

r^{-2}

$-\frac{r^{-1}}{-1}$

$\frac{-1}{r}$

$-\frac{1}{r_1} + \frac{1}{r_o}$ $\quad \left(\frac{1}{r_o} - \frac{1}{r_1}\right)$

With You Step By Step

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$N_B = 0$ for stagnent layer:-

$$\therefore \bar{N}_A = -4\pi r^2 \cdot D_{AB} \frac{dC_A}{dr} + \frac{C_A}{C_T}\left[\bar{N}_A + 0\right]$$

$$\therefore \bar{N}_A (1 - C_A) = -4\pi r^2 D_{AB} \cdot C_T \frac{dC_A}{dr}$$

$$\bar{N}_A \int_{r_0}^{r_1} \frac{dr}{r^2} = 4\pi D_{AB} C_T \ln\left[\frac{C_T - C_{A_2}}{C_T - C_{A_1}}\right]$$

$$\boxed{\bar{N}_A = \frac{4\pi D_{AB} C_T}{\frac{1}{r_0} - \frac{1}{r_1}} \ln\left[\frac{C_T - C_{A_2}}{C_T - C_{A_1}}\right]}$$ stagnent

if area is constant

$$N_A (4\pi r_0^2) = \frac{4\pi D_{AB} C_T}{1/r_0 - 1/r_1} \ln\left[\frac{C_T - C_{A_2}}{C_T - C_{A_1}}\right] \quad \text{--①}$$

$$N_A = \frac{D_{AB} \cdot C_T}{(1/r_0 - 1/r_1) r_0^2} \ln\left[\frac{C_T - C_{A_2}}{C_T - C_{A_1}}\right]$$

molar flux for the sphare surface

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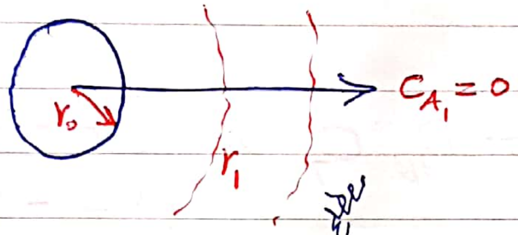
Large surface $\therefore r_1 \rightarrow \infty$

$\therefore C_{A_2} = 0$

$$\boxed{\therefore N_A = \frac{D_{AB} \cdot C_T}{r_0} \ln \frac{C_T - C_{A_2}}{C_T - C_{A_1}}} \quad \text{--- (3)}$$

r_0

$\left(\frac{1}{r_0}\right) \cancel{r_0^2}$



eq (3) in term of partial pressure.

$$\boxed{N_A = \frac{D_{AB} \cdot P_T}{r_0 \cdot R \cdot T} \ln \left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}}\right]}$$

With You Step By Step

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Ex) A sphere of naphthalene having a radius of 2mm is suspended in a large volume of still air at 318 K and 101.3 kpa. The surface temp. of Naphthalene can be assumed to be 318 K and its vapour pressure at this temp. is 0.555 mmHg. The diffusivity of naphthalene in air at 318 K ~~and 101.3 kpa~~ is 6.92×10^{-6} m^2/s. Calculate the rate of evaporation from surface.

$N_B = 0$

find the partial pressure of naphthalene at distance 30 mm from the surface of the naphthalene.

Sol)

(2 + 30 mm) , N_A = ثابت , نجد $P_{A_2} = ?$

$r_1 \rightarrow \infty \quad \therefore \quad P_{A_2} = 0$ [as the sphare suspended in alarge volume of air]

$$N_A = \frac{D_{AB} \cdot P_T}{r_o \cdot R \cdot T} \ln \left[\frac{P_T - P_{A_2}}{P_T - P_{A_1}} \right]$$

$$N_A = \frac{6.92 \times 10^{-6} \times 101.3}{8.314 \times 2 \times 10^{-3} \times 318} \ln \left[\frac{101.3 - 0}{101.3 - 0.0739} \right]$$

$$= 9.68 \times 10^{-8} \ Kmol/s.m^2$$

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Case (II) : equimolecular counter Diffusion

$$\frac{\bar{N}_A}{A} = -D_{AB}\frac{dC_A}{dr} + \frac{C_A}{C_T}\left(\frac{\bar{N}_A}{A} - \frac{\bar{N}_B}{A}\right)$$

$$\bar{N}_A = -4\pi r^2 D_{AB}\frac{dC_A}{dr}$$

$$\bar{N}_A\int_{r_0}^{r_1}\frac{dr}{r^2} = -4\pi D_{AB}\int_{C_{A_1}}^{C_{A_2}} dC_A$$

$$\boxed{\therefore \bar{N}_A = \frac{4\pi D_{AB}}{\frac{1}{r_0} - \frac{1}{r_1}}(C_{A_1} - C_{A_2})}$$

from the mass transfer from surface

$$\therefore A = 4\pi r_0^2$$

$$\therefore N_A = \frac{D_{AB}}{r_0^2\left[1/r_0 - 1/r_1\right]}(C_{A_1} - C_{A_2})$$

in the case of r_1 is very large $\boxed{\frac{1}{r_1} = 0}$

$$\boxed{N_A = \frac{D_{AB}}{r_0}\left[C_{A_1} - C_{A_2}\right]}$$

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Case (III):- unimolecular counter D.

Ex)
$$\boxed{N_A = \frac{D_{AB}}{R.T} \cdot \frac{P_T}{r_0} \cdot \frac{1}{1-n} \ln\left[\frac{P_T-(1-n)P_{A_2}}{P_T-(1-n)P_{A_1}}\right]}$$

Ex) Calculate the rate of burning of carbon particle 2.56 cm radius in an atm. of pure oxygen at 1000 K and 1 atm. Assuming a very blanking layer of CO_2 has formed a round the partical. At the carbon surface $P_{CO_2} = 1$ atm and $P_{O_2} = 0$. At very large radius $P_{CO_2} = 0$ and $P_{O_2} = 1$ atm. Given the diffusivity of oxygen in carbon dioxide = 1.032 cm^2/s.

Sol)

$$C + O_2 \longrightarrow CO_2$$ ∴ diffusion equimolecular counter diffusion.

$$N_A = \frac{D_{AB}}{R.T.r_0^2\left[1/r_0 - \frac{1}{r_1}\right]}(P_{A_1} - P_{A_2})$$

$r_1 \longrightarrow \infty$, $\frac{1}{r_1} = 0$

$\frac{\rho}{MW}$

DATE 12/26 OBJECT

$$N_A = \frac{1.032\times10^{-4}}{(8.314)(1000)(2.56\times10^{-4})}(101.3-0)$$

$$= 4.95\times10^{-5} \text{ kmole/s}$$

مهم جدا

* Moleculer Diffusion of liquid :-

$$J_A = -\underset{(\text{liquid})}{D_L}\frac{dc_A}{dz}$$

$$N_A = -D_L\frac{dc_A}{dz} + \frac{C_A}{C_B}[N_A+N_B]$$

equimola ---- $N_A = -N_B$

$$\boxed{N_A = -D_L\left[\frac{C_{A_2}-C_{A_1}}{z_2-z_1}\right]} \text{ ---- ①}$$

or $x_{A_1} = \frac{C_{A_1}}{C_T}$; $x_{A_2} = \frac{C_{A_2}}{C_T}$

$$\therefore \boxed{N_A = +D_L\cdot C_{average}\left[\frac{x_{A_1}-x_{A_2}}{z_2-z_1}\right]} \text{ --- ②}$$

$$C_{av} = \frac{\frac{\rho_1}{Mwt_1} + \frac{\rho_2}{Mwt_2}}{2} = \text{Kmole}/m^3$$

* Diffusion of liquid:-

$$N_A = -D_L \frac{dc_A}{dz} + \frac{C_A}{C_T}\left[N_A + N_B\right]$$

in $N_A = -N_B \Rightarrow$

$$N_A = -D_L\, C_{av} \left[\frac{x_{A_2} - x_{A_1}}{\Delta z}\right] \quad \text{.....(1)}$$

eq(1) can be written when $= 0$

$$N_A = -D_L \frac{C_{av}}{x_{BLm}} \left[\frac{x_{A_1} - x_{A_2}}{z_2 - z_1}\right] \qquad x_{BLm} = \frac{x_{B_2} - x_{B_1}}{\ln \frac{x_{B_2}}{x_{B_1}}}$$

that from:-

$$N_A = -D_L \cdot \frac{dc_A}{(C - C_A)\, dz}$$

$$\therefore N_A = -D_L \cdot \frac{[x_{A_2} - x_{A_1}]}{C[1 - x_A]\, dz}$$

$$\cdot \frac{D_L\, C_{av}}{dZ\ x_{BM}} \quad (x_{A_1} - x_{A_2})$$

DATE 28 OBJECT

$$N_A \int_{Z_1}^{Z_2} dZ = -D_L\, C_{av} \int_{x_{A_1}}^{x_{A_2}} \frac{dx_A}{(1-x_A)}$$

x_B

$$\boxed{N_A = -D_L \cdot \frac{C_{av}}{\Delta Z} \ln \frac{x_{B_2}}{x_{B_1}}} \quad \text{--- (1)}$$

$$x_{BLm} = \frac{x_{B_2} - x_{B_1}}{\ln \frac{x_{B_2}}{x_{B_1}}}$$

$$\therefore \boxed{\ln \frac{x_{B_2}}{x_{B_1}} = \frac{x_{B_2} - x_{B_1}}{x_{BLm}}} \quad \text{--- (2)}$$

sub (2) in (1)

$$\boxed{N_A = D_L \cdot \frac{C_{av}}{\Delta Z \cdot x_{BLm}} (x_{A_1} - x_{A_2})}$$

$x_{BLm} = 1$ for

(ϕ)

assation factor

$$\frac{D_{AB}}{\text{liquid}} = \left[\frac{7.4 \times 10^{-8} (\phi_B \cdot MWt_B)^{1/2} \cdot T}{\mu_B \cdot V_A^{0.6}} \right] (*)$$

association factor

or

$$\frac{1.173 \times 10^{-6} [\phi_B\, M_B]^{0.5} \cdot T}{\mu\ V_A^{0.6}}$$

C_2H_5OH

DATE 29 OBJECT

Ex) ethanol (A) in water solution in the form of a stagnant film 2 mm thick at 293 K. (water is in ~~solution~~ soluble ethanol is soluble) At point ① the concentration of ethanol 16.8% and the density = 972.8 kg/m³. at point ② ethanol con. 6.8 wt% and ρ_2 = 988.1 kg/m³;

$D_{AB} = 2.87 \times 10^{-5}$ kg/m³

sol)

$$N_A = \frac{D_{AB} \cdot C_{av}}{(Z_2 - Z_1)\, x_{BLm}} (x_{A_1} - x_{A_2})$$

$$x_{B_1} = 1 - x_A = 1 - \frac{16.8/46.05}{\frac{16.8}{46} + \frac{83.2}{18}} \Rightarrow 0.9268$$

$$x_{B_2} = 1 - x_{A_2} \Rightarrow 1 - \frac{6.8/46}{\frac{6.8}{46} + \frac{93.2}{18}} \Rightarrow 0.9723$$

$$M_1 = \frac{100}{\frac{16.8}{46.08} + \frac{83.2}{18.02}} = 20.07$$

$$MW_{(mix)} = \frac{wt(total)}{\frac{wt(A)}{MWt(A)} + \frac{wt(B)}{MW(B)}}$$

$$M_2 = 18.75$$

$$\therefore C_{av} = \frac{\frac{\rho_1}{M_1} + \frac{\rho_2}{M_2}}{2} = 50.6$$

$$x = \frac{wt}{MWt}$$

sema NOTEBOOK & STATIONERY

DATE 30/ OBJECT

$$x_{BLm} = \frac{x_{B_1} + x_{B_2}}{2}$$ for dilute solution $= 0.949$

$$\therefore N_A = \frac{(0.74 \times 10^{-4}) \times 50.6 \times (0.0732 - 0.0277)}{2 \times 10^{-3} \times 0.949}$$

$$= 8.97 \times 10^{-7} \ \text{kmol/m}^2.\text{s}$$

$N_B = 0$

H.W) Calculate the rate of diffution of acetic acide (A.C) across a film of non-diffusing water of 1mm at 17C° the con. of A = 9 wt% and 3wt, respectivary. $D_{AB} = 0.95 \times 10^{-9}$ m²/s ; specific gravity of (Ac) = 1.049

With You Step By Step

DATE / / OBJECT

$$N_A = \frac{D_L \cdot C_{av}}{\Delta Z \cdot x_{BLm}} (x_{A_1} - x_{A_2})$$

$$x_{A_1} = \frac{9/60}{9/60 + 91/18} = 0.0288$$

$$x_{A_2} = \frac{3/60}{3/60 + 97/18} = 0.0092$$

$$x_{B_1} = 1 - x_{A_1} = 0.9712$$

$$x_{B_2} = 1 - x_{A_2} = 0.9908$$

$$x_{BLm} = \frac{x_{B_2} - x_{B_1}}{\ln \frac{x_{B_2}}{x_{B_1}}} = 0.981$$

$$\rho_1 = wt_{AC_1} \times \rho_{AC} + wt_{water_1} \times \rho_{water}$$

$$= 0.09 \times 1.049 + 0.91 \times 1$$

$$= 1004.41 \text{ kg/m}^3$$

$$\rho_2 = wt_2 \times \rho_{Ac} + wt_2 \times \rho_{water}$$

$$= 1001.47 \text{ kg/m}^3$$

DATE / / OBJECT

$$\mathcal{M}_1 = \frac{100}{\frac{9}{60} + \frac{91}{18}} = 19.2$$

$$\mathcal{M}_2 = 18.3$$

$$C_{av} = \frac{(1004.41/19.2) + (1001.47/18.3)}{2} = 53.3 \ \frac{\text{kmol}}{m^3}$$

$$N_A = \frac{0.95 \times 10^{-9} \times 53.3}{0.981 \times 0.001} \times (0.0092 - 0.0288)$$

$$= 9.318 \times 10^{-7} \ \text{kmol}/m^2 * s$$

DATE 3 / / OBJECT نقل كتلة الحمل الحراري لخليط الغاز ثنائي

⊛ Convective (M.T.C) for Binary mixture.

$$N_A = -C*(D_{AB} + E_D)\frac{dx_A}{dZ} + x_A[N_A + N_B]$$

الدوامة

E_D = The eddy diffusion.

$$\boxed{N_A = \frac{D_{AB} + E_D}{R.T} \times \frac{P_{A_1} - P_{A_2}}{Z_2 - Z_1}}$$

$\Downarrow$

K'_G

gas ⇒ $N_A = K'_G(P_{A_1} - P_{A_i})$ or $N_A = K'_y(y_{A_1} - y_{A_2})$

K'_G = individual mass transfer coeff.

liquid ⇒ $N_A = K'_L(C_{A_1} - C_{A_2}) = K'_x(x_{A_1} - x_{A_2})$

DATE 32 OBJECT

$$N_A = \frac{(D_{AB} + E_D) \times P_T}{R \cdot T \cdot P_{BLm}} \times \frac{P_{A_1} - P_{A_2}}{(Z_2 - Z_1)}$$

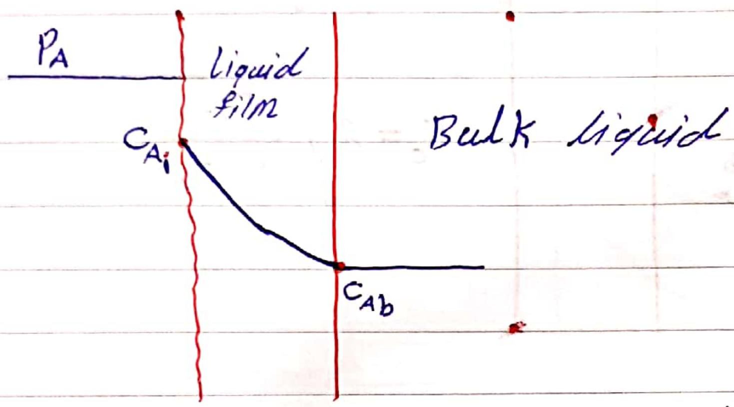
gas $\begin{cases} N_A = K_G \, (P_{A_1} - P_{A_2}) \\ N_A = K_y \, (y_{A_1} - y_{A_2}) \end{cases}$ for uni molecular mass transfer.

liquid $\begin{cases} N_A = K_L \, (C_{A_1} - C_{A_2}) \\ N_A = K_x \, (x_{A_1} - x_{A_2}) \end{cases}$

DATE 3/3 OBJECT

⊗ theory

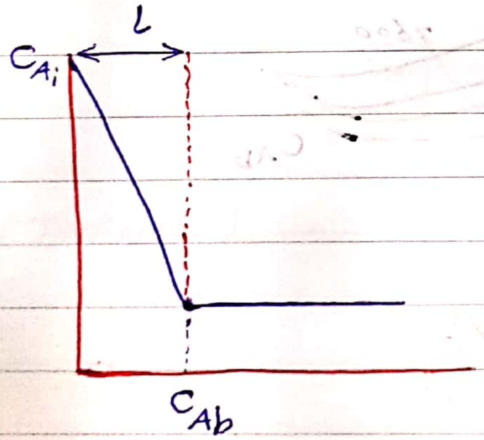
① Film Theory (steady state)



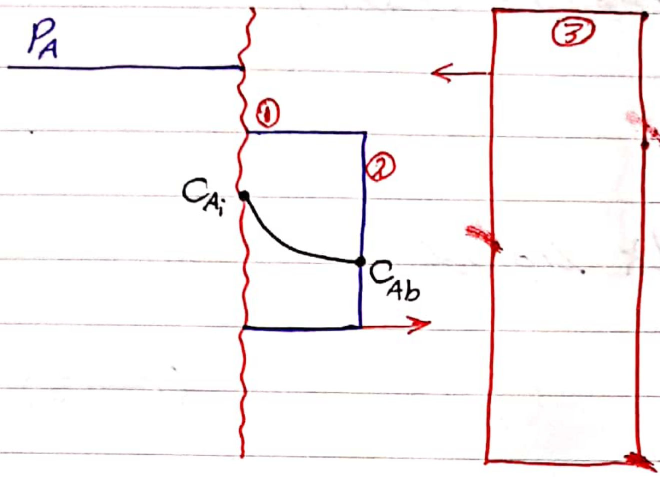
(Gas)

$z=0$ $z=\delta_L$ ⇒ stagnant liquid film of thickness

$$N_A = \frac{D_{AB}}{\delta}\left(C_{A_i} - C_{A_b}\right)$$

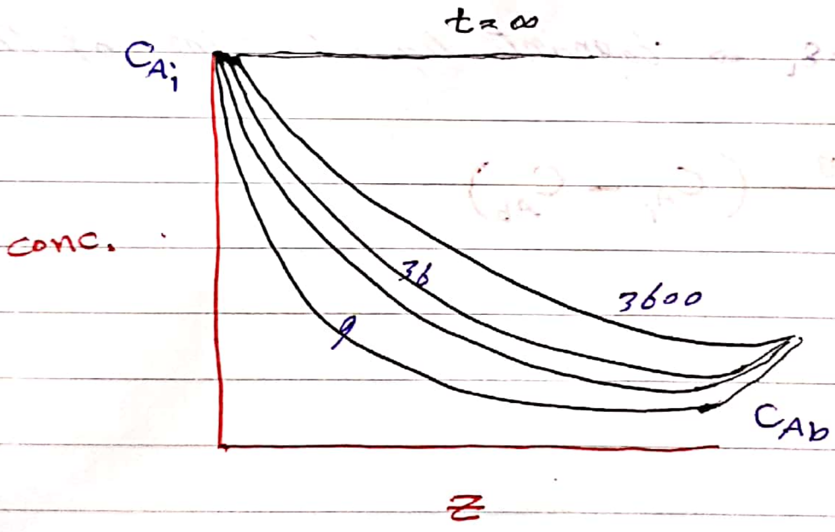


② penetration theory :- (un steady state)



$$N_A = 2\sqrt{\frac{D_{AB}}{\pi \cdot t_c}} \cdot (C_{A_i} - C_{Ab})$$

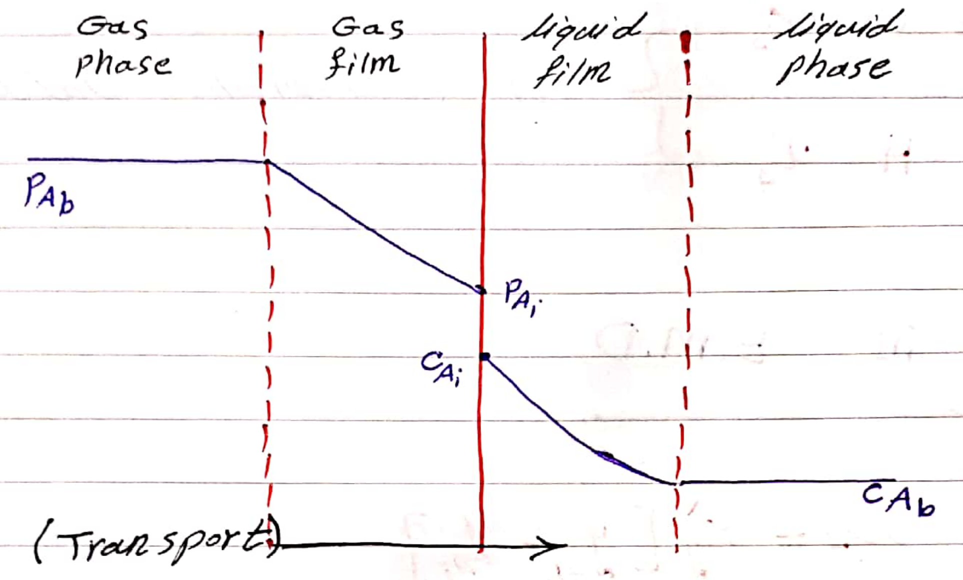
$$k_c = 2\sqrt{\frac{D_{AB}}{\pi \cdot t_c}}$$

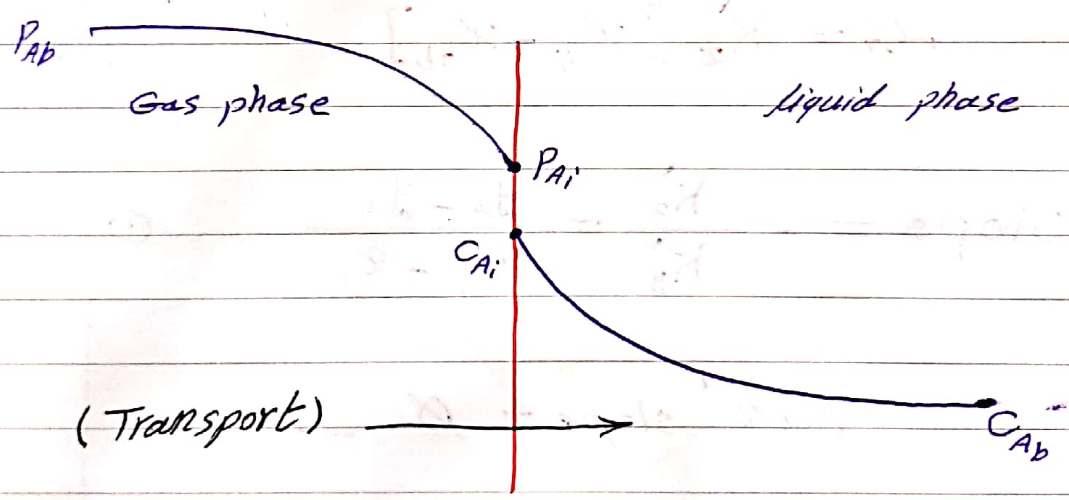


$$\frac{dC_A}{dt} = D \frac{d^2 C_A}{dy^2}$$

DATE 35 OBJECT

③ Two - Film Theory :- steady-state (gas-liquid)





$$N_A = \frac{(D_{AB})_G}{\delta_G} (C_{A_b} - C_{A_i})_G \quad \text{for gas}$$

$$N_A = \frac{(D_{AB})_L}{\delta_L} (C_{A_i} - C_{A_b})_L \quad \text{for Liq.}$$

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DATE / 36 OBJECT

P. 61

$$y_A = m\, x_A^* \quad ; \quad P_A^* = H\, x_A$$ for equilibrum Data.

- Case [1] E.M.D

E.M.D $\Rightarrow$ $N_A = K_y' [y_{Ab} - y_{Ai}]$

$N_A = K_x' [x_{Ai} - x_{Ab}]$ $\boxed{x_A = x_{Ab}}$

$$\text{slope} = -\frac{K_x'}{K_y'} = \frac{y_A - y_{Ai}}{x_{Ai} - x_A} \quad \text{--- (1)}$$

$\tan^{-1}$ slope $= \phi$

With You Step By Step

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DATE 37 OBJECT

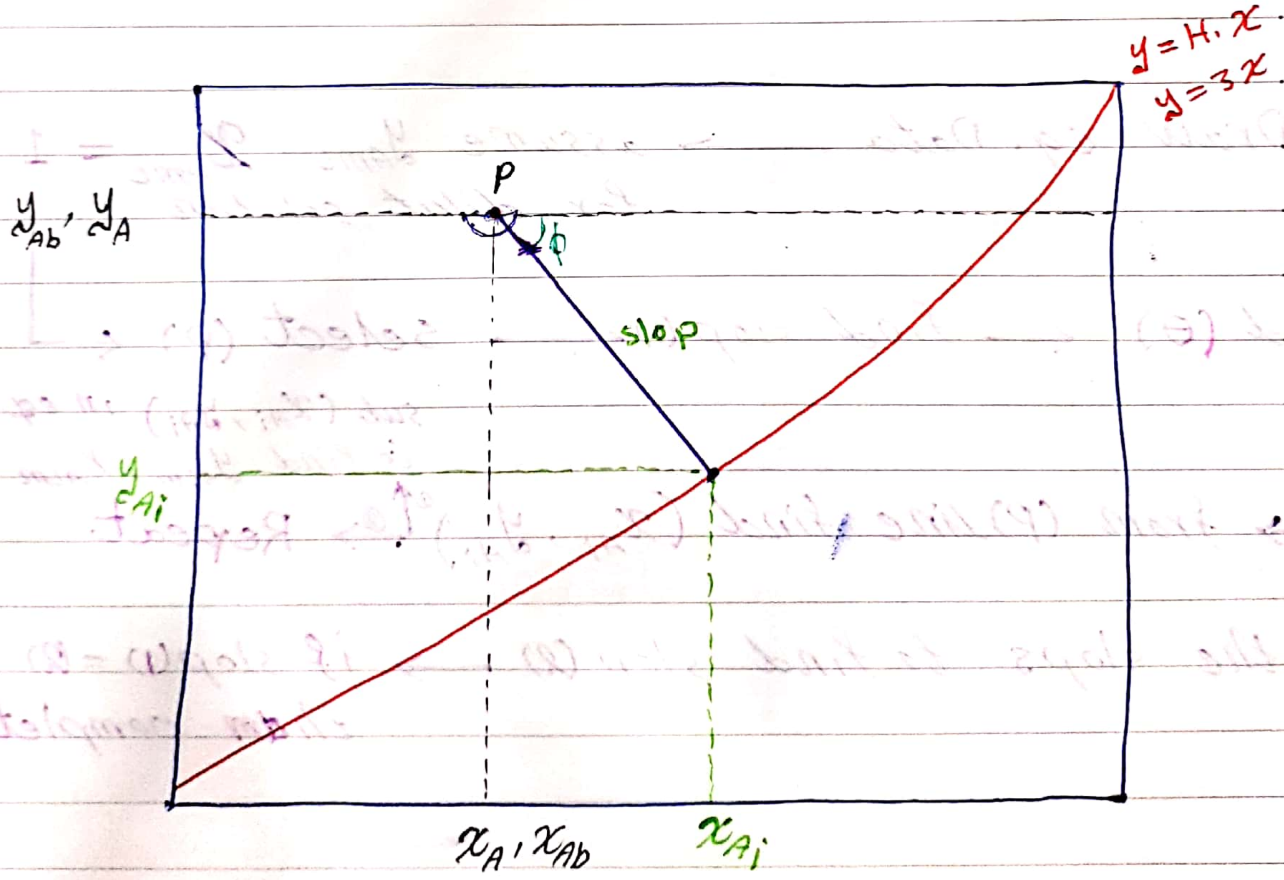
- How calculate y_{A_i} and x_{A_i} :-

Draw eq. Data ⟶ select (p)

Draw a stagnant line from (p) with slop $\left(-\frac{k'_x}{k'_y}\right)$

⟶ interject eq. curve with x_{A_i}, y_{A_i}

find the flux ⟵ Read x_{A_i} and y_{A_i}



DATE 1/38 OBJECT

Case $\boxed{2}$ p.83 u.m.D

$$N_A = K_y (y_A - y_{A_i}) = K_x (x_{A_i} - x_A) \quad \text{--- (1)}$$

$$N_A = \frac{K'_y}{y_{ALm}} (y_A - y_{A_i}) = \frac{K'_x}{x_{ALm}} (x_{A_i} - x_A)$$

$$\boxed{\text{Slop} = -\frac{K_x}{K_y} = \frac{y_A - y_{A_i}}{x_{A_i} - x_A} = \frac{-K'_x/\cancel{x}_{ALm}}{K'_y/\cancel{y}_{ALm}}} \quad \text{--- (2)}$$

- How calculate y_{A_i}, x_{A_i} for u.m.D

Draw eq. Data ⟶ assume y_{AML}, $x_{AML} = 1$ for dilut solution

find (θ) ⟵ find slop (1) ⟵ select (P)

sub (x_{A_i}, y_{A_i}) in eq (3) to find y_{ALm}, x_{ALm}

↳ from (P) line find (x_{A_i}, y_{A_i}) (1) ↑ (2) ⟶ Repeat

the slops to find slop (2) ⟶ if slop (1) = (2) then complete

With You Step By Step

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DATE 3/9/ OBJECT

$$x_{A,Lm} = \frac{(1-x_A)-(1-x_{Ai})}{\ln \frac{(1-x_A)}{(1-x_{Ai})}}$$

$$y_{A,Lm} = \frac{(1-y_{Ai})-(1-y_A)}{\ln \frac{(1-y_{Ai})}{(1-y_A)}}$$

--- ③

(u.m.d)

① يحدث هذا الانتشار في أماكن مفتوحة أي أنبوب مفتوح أو وعاء مفتوح.

② من كتابة كلمة (stagnant)

③ من كتابة كلمة (large volume)

④ انتشار من وعاء يحتوي ماء الى هواء.

- Overall Driving force:-

$(y_A - y_A^*)$ overall driving force gas

$(x_A^* - x_A)$ overall driving force liquid

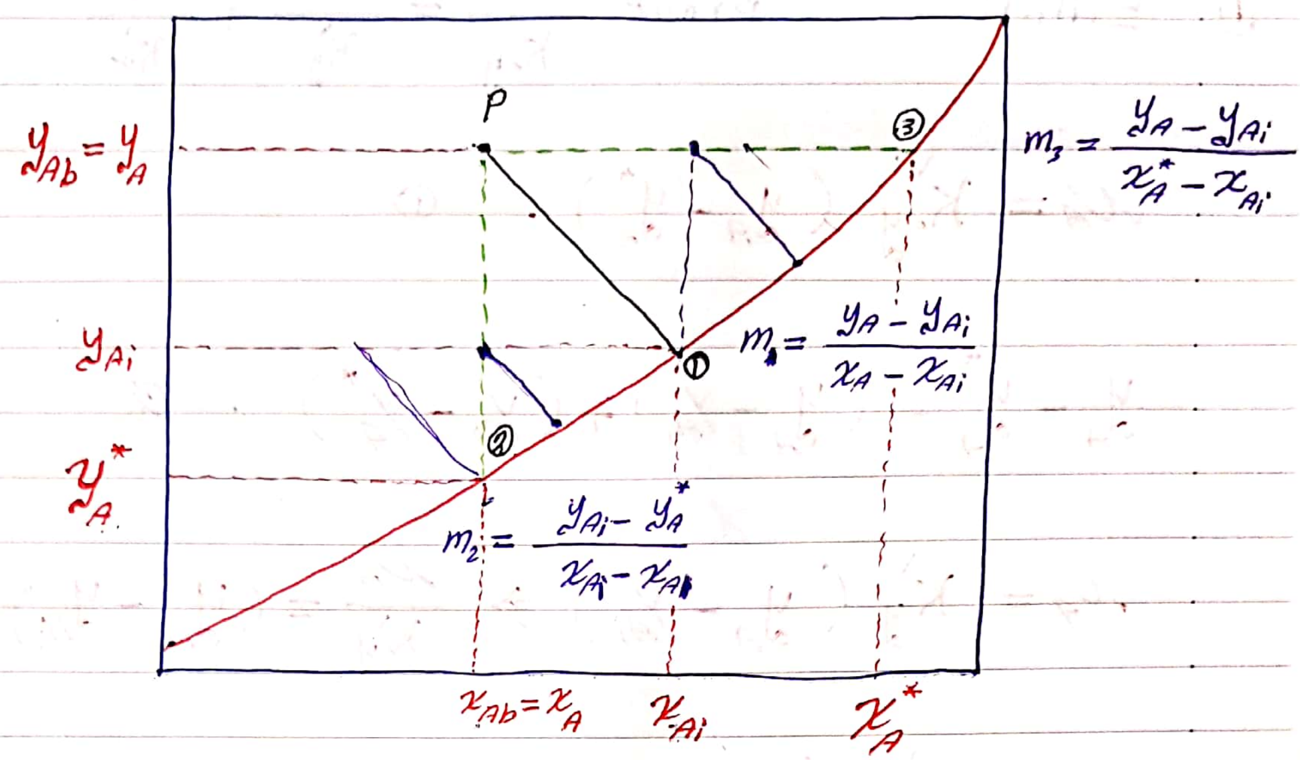
$$N_A = K'_{oy} (y_A - y_A^*) \quad \text{--- (E.M.D)}$$

$$N_A = K_{oy} (y_A - y_A^*) \quad \text{--- (U.M.D)}$$

$$N_A = K'_{ox} (x_A^* - x_A) \quad \text{--- (E.M.D)}$$

$$N_A = K_{ox} (x_A^* - x_A) \quad \text{--- (U.M.D)}$$

DATE 4/1 OBJECT



$$m_2 = \frac{y_{Ai} - y_A^*}{x_{Ai} - x_A}$$

$$m_1 = \frac{y_A - y_{Ai}}{x_{Ai} - x_A}$$

$$m_3 = \frac{y_A - y_{Ai}}{x_A^* - x_{Ai}}$$

DATE 1 42 OBJECT

1 E.M.D prove $\frac{1}{K'_{oy}} = \frac{1}{K'_y} + \frac{m^2}{K'_x}$

$$N_A = K'_{oy}\,(y_A - y_A^*) \quad \text{--- (1)}$$

$$y_A - y_A^* = (y_A - y_{Ai}) + (y_{Ai} - y_A^*) \quad \text{--- (2)}$$

$$N_A = K'_y\,(y_A - y_{Ai}) \Rightarrow \frac{N_A}{K'_y} = (y_A - y_{Ai}) \quad \text{--- (3)}$$

$$N_A = K'_x\,(x_A - x_{Ai}) \Rightarrow \frac{N_A}{K'_x} = (x_A - x_{Ai}) \quad \text{--- (4)}$$

from eq (1) and eq (2)

$$(y_A - y_A^*) = \frac{N_A}{K'_y} + (y_{Ai} - y_A^*)$$

$$m^2 = \frac{y_{Ai} - y_A^*}{x_A - x_{Ai}} \quad \text{--- (5)}$$

$$(y_A - y_A^*) = \frac{N_A}{K'_y} + m^2\,\frac{N_A}{K'_x}$$

$$N_A = \frac{K'_{oy} \cdot N_A}{K'_y} + m^2\,\frac{K'_{oy}\,N_A}{K'_x}$$

DATE 4/3/ OBJECT

$$\frac{N_A}{K'_{oy}} = \frac{N_A}{K'_y} + \frac{m^2 N_A}{K'_x} \quad * \left(\frac{1}{N_A}\right)$$

$$\frac{1}{K'_{oy}} = \frac{1}{K'_y} + \frac{m^2}{K'_x}$$

H.W)
$$\frac{1}{K'_{ox}} = \frac{1}{m^3 K'_y} + \frac{1}{K'_x}$$

y_A

y_{Ai}

$\cancel{y}^*$

x_A x_{Ai} x_A^*

sema NOTEBOOK & STATIONERY

DATE / / OBJECT

prove $\Rightarrow \dfrac{1}{K'_o x} = \dfrac{1}{m^3 K'_y} + \dfrac{1}{K'_x}$

$$N_A = K'_{ox}\,(x_A^* - x_A) \quad \text{---} (1)$$

$$x_A^* - x_A = (x_A^* - x_{Ai}) + (x_{Ai} - x_A) \quad \text{---} (2)$$

$$N_A = K'_x\,(x_{Ai} - x_A) \Rightarrow \frac{N_A}{K'_x} = (x_{Ai} - x_A) \quad \text{---} (3)$$

$$N_A = K'_y\,(y_A - y_{Ai}) \Rightarrow \frac{N_A}{K'_y} = (y_A - y_{Ai}) \quad \text{---} (4)$$

from eq (1) and eq (2)

$$x_A^* - x_A = (x_A^* - x_{Ai}) + \frac{N_A}{K'_x}$$

$\dfrac{N_A}{K'_y} \times \dfrac{1}{m^3}$

$$m^3 = \frac{y_A - y_{Ai}}{x_A^* - x_{Ai}} \Rightarrow$$

$$x_A^* - x_A = \frac{\frac{N_A}{K'_y}}{m^3} + \frac{N_A}{K'_x}$$

$$\frac{N_A}{K'_{ox}} = \frac{N_A}{K'_y \cdot m^3} + \frac{N_A}{K'_x} \qquad * \left(\frac{1}{N_A}\right)$$

$$\frac{1}{K'_{ox}} = \frac{1}{K'_y \cdot m^3} + \frac{1}{K'_x}$$

Q: Prove that $\dfrac{1}{K_{OG}} = \dfrac{1}{k_g} + \dfrac{H}{k_L}$

From Eq.(3) above:

$$\frac{1}{K_{OG}} = \frac{P_A - P_A^*}{N_A}$$

$$\frac{1}{K_{OG}} = \frac{P_A - P_A^* + P_{A_i} - P_{A_i}}{N_A}$$

$$\frac{1}{K_{OG}} = \frac{P_A - P_{A_i}}{N_A} + \frac{P_{A_i} - P_A^*}{N_A}$$

$$\frac{1}{K_{OG}} = \frac{P_A - P_{A_i}}{N_A} + \frac{H\,C_{A_i} - H\,C_A}{N_A}$$

$$\frac{1}{K_{OG}} = \frac{P_A - P_{A_i}}{N_A} + \frac{H\,(C_{A_i} - C_A)}{N_A}$$

$$\frac{1}{K_{OG}} = \frac{1}{k_g} + \frac{H}{k_L}$$

Q: Prove that $\frac{1}{K_{OL}} = \frac{1}{H\,k_g} + \frac{1}{k_L}$

From Eq.(4) above:

$$\frac{1}{K_{OL}} = \frac{C_A{}^* - C_A}{N_A}$$

$$\frac{1}{K_{OL}} = \frac{C_A{}^* - C_A + C_{A_i} - C_{A_i}}{N_A}$$

$$\frac{1}{K_{OL}} = \frac{C_A{}^* - C_{A_i}}{N_A} + \frac{C_{A_i} - C_A}{N_A}$$

$$\frac{1}{K_{OL}} = \frac{\frac{P_A}{H} - \frac{P_{A_i}}{H}}{N_A} + \frac{C_{A_i} - C_A}{N_A}$$

$$\frac{1}{K_{OL}} = \frac{1}{H}\left(\frac{P_A - P_{A_i}}{N_A} + \frac{C_{A_i} - C_A}{N_A}\right)$$

$$\frac{1}{K_{OL}} = \frac{1}{H\,k_g} + \frac{1}{k_L}$$

250

آ م كيمياوي
أحمد طالب

Example 14

A solute (A) is being diffused from a gas mixture of A & B in a wetted wall column with a liquid flowing as a film downwards along the wall. At a certain point in the column the gas bulk contains A of y_A=0.38 (mole fraction) and at the liquid bulk the concentration of A is x_A= 0.1 mole fraction.
The column is operated at 1 atm and 25 °C and the equilibrium data in such conditions are as follow:

x_A	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35
y_A	0	0.022	0.052	0.087	0.131	0.187	0.265	0.38

The solute A is diffusing through stagnant layer of B and then through non – diffusing liquid. Given the individual mass transfer coefficient for equi – molar mass transfer for both gas and liquid phases as:

$$K'_y = 1.465 * 10^{-3} \frac{kmol\ A}{s * m^2 * mole\ fraction}$$

$$K'_x = 1.967 * 10^{-3} \frac{kmol\ A}{s * m^2 * mole\ fraction}$$

Calculate the interfacial composition and the flux N_A.

Solution

Since we are dealing with a mass transfer operation through stagnant layer, therefore we can not use the slop as:

$$slop = -\frac{K'_x}{K'_y} = \frac{(y_A - y_{A_i})}{(x_A - x_{A_i})}$$

But we must use the form:

$$Slop = -\frac{K'_x / x_{A_{iLM}}}{K'_y / y_{A_{iLM}}}$$

Then:

1- Draw the equilibrium curve.
2- Plot point P (y_A = 0.38, x_A = 0.1).
3- Assume $y_{A_{iLM}}$ and $x_{A_{iLM}}$ =1.
4- Draw a line from point P with a slop of:

$$slop = -\frac{K'_x}{K'_y} = \frac{-1.967 * 10^{-3}}{1.465 * 10^{-3}} = -1.342662116$$

5- Extent the line until it will intercept the equilibrium curve at point (m).

6- Read $(x_{Ai})_1$ and $(y_{Ai})_1$

$(x_{Ai})_1 = 0.246$ and $(y_{Ai})_1 = 0.18$

7- Calculate $y_{A_{iLM}}$ And $x_{A_{iLM}}$.

$$x_{A_{iLM}} = \frac{(1-x_A)-(1-x_{A_i})}{\ln\frac{(1-x_A)}{(1-x_{A_i})}} = \frac{(1-0.1)-(1-0.246)}{\ln\frac{(1-0.1)}{(1-0.246)}} = 0.824847594$$

And

$$y_{A_{iLM}} = \frac{(1-y_{A_i})-(1-y_A)}{\ln\frac{(1-y_{A_i})}{(1-y_A)}} = \frac{(1-0.38)-(1-0.18)}{\ln\frac{(1-0.38)}{(1-0.18)}} = 0.715346711$$

8- Recalculate the slop using the equation:

$$Slop = -\frac{K'_x/x_{A_{iLM}}}{K'_y/y_{A_{iLM}}} = \frac{-1.967*10^{-3}/0.824847594}{1.465*10^{-3}/0.715346711} = -1.164419871$$

Since $(slop)_1 \neq (slop)_2$

1- Draw a second line of slop = - 1.164419871

10- Read $(x_{Ai})_1$ and $(y_{Ai})_1$

$(x_{Ai})_1 = 0.258$ and $(y_{Ai})_1 = 0.199$

11- Calculate $y_{A_{iLM}}$ And $x_{A_{iLM}}$.

$$x_{A_{iLM}} = \frac{(1-x_A)-(1-x_{A_i})}{\ln\frac{(1-x_A)}{(1-x_{A_i})}} = \frac{(1-0.1)-(1-0.258)}{\ln\frac{(1-0.1)}{(1-0.258)}} = 0.818459811$$

And

$$y_{A_{iLM}} = \frac{(1-y_{A_i})-(1-y_A)}{\ln\frac{(1-y_{A_i})}{(1-y_A)}} = \frac{(1-0.38)-(1-0.199)}{\ln\frac{(1-0.38)}{(1-0.199)}} = 0.70664075$$

12- Recalculate the slop using the equation:

$$Slop=-\frac{K'_x/x_{A_{iLM}}}{K'_y/y_{A_{iLM}}}=\frac{-1.967*10^{-3}/0.81845811}{1.465*10^{-3}/0.70664075}=-1.159225845$$

Since $(slop)_2 \neq (slop)_3$

13-Draw a second line of slop = - 1.159225845

14- Read $(x_{Ai})_1$ and $(y_{Ai})_1$

$(x_{Ai})_1 = 0.257$ and $(y_{Ai})_1 = 0.199$

15- Calculate $y_{A_{iLM}}$ And $x_{A_{iLM}}$.

$$x_{A_{iLM}}=\frac{(1-x_A)-(1-x_{A_i})}{\ln\frac{(1-x_A)}{(1-x_{A_i})}}=\frac{(1-0.1)-(1-0.257)}{\ln\frac{(1-0.1)}{(1-0.257)}}=0.819$$

And

$$y_{A_{iLM}}=\frac{(1-y_{A_i})-(1-y_A)}{\ln\frac{(1-y_{A_i})}{(1-y_A)}}=\frac{(1-0.38)-(1-0.199)}{\ln\frac{(1-0.38)}{(1-0.199)}}=0.70664$$

16- Recalculate the slop using the equation:

$$Slop=-\frac{K'_x/x_{A_{iLM}}}{K'_y/y_{A_{iLM}}}=\frac{-1.967*10^{-3}/0.819}{1.465*10^{-3}/0.70664}=-1.15846$$

Since $(slop)_3 \approx (slop)_4$

Then we have reached the correct interface composition which is equal to:

$(x_{Ai})_1 = 0.257$ and $(y_{Ai})_1 = 0.199$

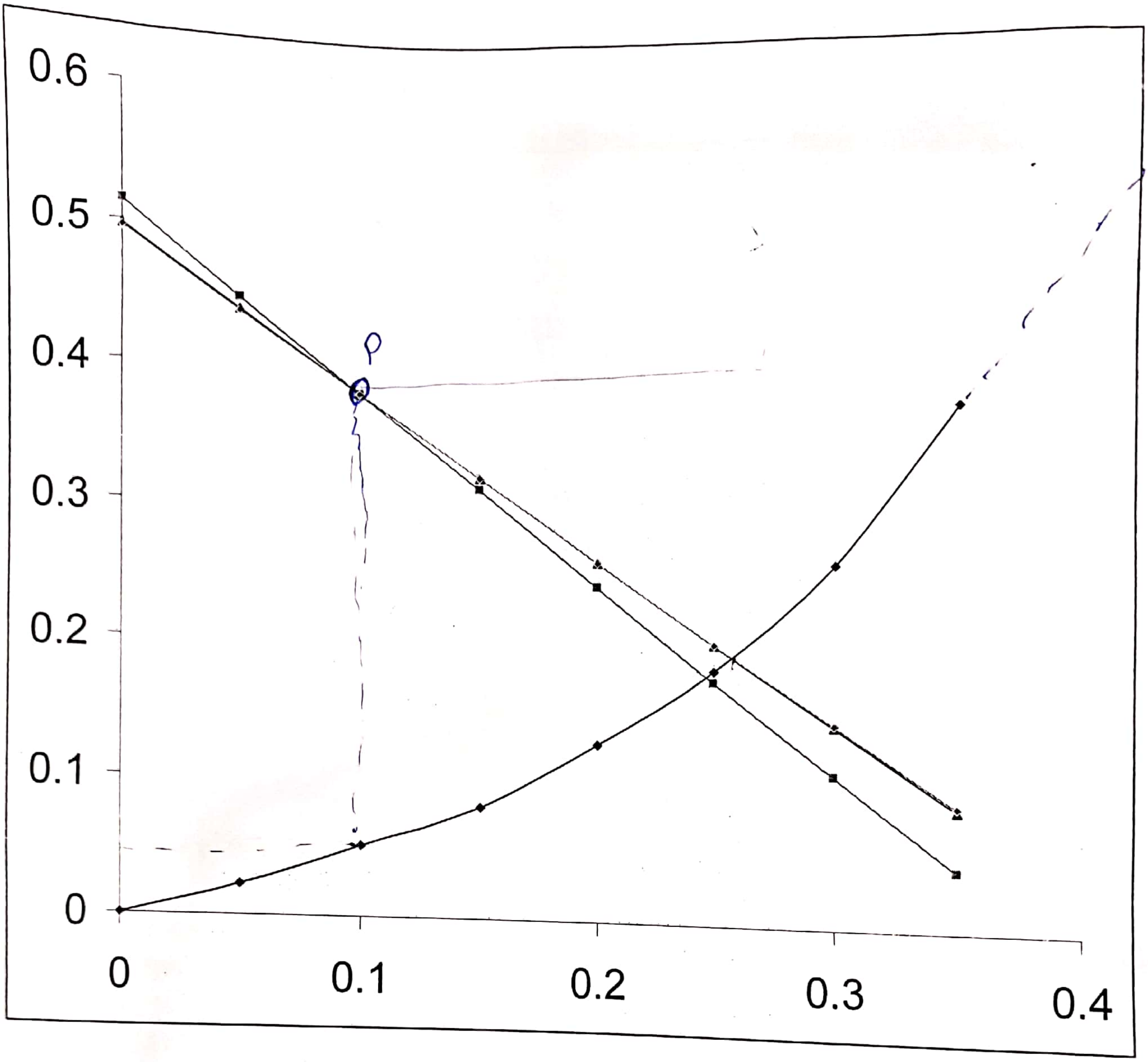
And

$x_{A_{iLM}} = 0.819$

$y_{A_{iLM}} = 0.70664$

$$N_A=K_y*(y_A-y_{A_i})=\frac{K'_y}{y_{A_{iLM}}}*(y_A-y_{A_i})=\frac{1.465*10^{-3}}{0.70664}*(0.38-0.2)$$

$$N_A=3.7317*10^{-4}\ \frac{kmol}{m^2*s}$$


0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
P

EX) calculate the overall Driving force (K_{oy}) the flux (N_A) an the precent resistance in the gas and liquid of total resistance. Take the same Data of (ex.14)

sol)

$$m_2 = \frac{y_{Ai} - y_A^*}{x_{Ai} - x_A} \Rightarrow \frac{0.2 - 0.052}{0.257 - 0.1} = 0.942$$

$$y^*_{ALm} = \frac{(1-y_A^*) - (1-y_A)}{\ln\left(\frac{1-y_A^*}{1-y_A}\right)} = 0.773$$

$$\Rightarrow K_y = \frac{K'_y}{y_{ALm}} = 2.07 \times 10^{-3}$$

$$K_x = \frac{K'_x}{x_{ALm}} = \frac{1.967 \times 10^{-3}}{0.819} = 2.4 \times 10^{-3}$$

in the same way

$$\Rightarrow \frac{1}{K'_{oy}} = \frac{1}{K'_y} + \frac{m_2}{K'_x}$$

$$\frac{1}{K'_{oy}} = 1161.85 \longrightarrow K'_{oy} = 8.607 \times 10^{-4}$$

$$\therefore K_{oy} = \frac{K'_{oy}}{y^*_{AiLm}} = 1.1134 \times 10^{-3}$$

$$N_A = K_{oy}[y_A - y^*_A] \Rightarrow 3.6 \times 10^{-4} \text{ Kmol/s.m}^2$$

$$\frac{1}{K_y} = \frac{y_{AiLm}}{K'_y} \doteq 482.3$$

$$\frac{m_2}{K_x} = \frac{m^2 \cdot x_{AiLm}}{K'_x} = 392.512$$

$$\therefore \frac{1}{K_{oy}} = \frac{y^*_{ALm}}{K'_{oy}} = 898.1062$$

- the present gas resistance $= \frac{\text{gas.R}}{\text{overall.R}} \times 100\%$

$= 53.7\%$

- The present liquid resistance $= \frac{\text{liquid R.}}{\text{overall R}} \times 100\%$

$= 43.7\%$

Ex) for a system in which (A) is transfering from liquid to gas phase $y_A^* = 0.75\, x_A$. At one point the liquid contains 90 mol% and gas 45%. $K_y = 0.0276$ kmol/s.m^2 and 70% of the overall resistance to mass transfer in gas film. ① The flux ② The interficial con. (A) ③ The overall M.T.C for L and g.

sol/

من كلام السؤال

$$\frac{1}{K_y} = 0.7\left(\frac{1}{K_{oG}}\right)$$

$$\frac{1}{0.0276} = 0.7\left(\frac{1}{K_{oy}}\right) \Rightarrow K_{og} = 0.019$$

$$N_A = K_{oy}\,(y_A^* - y_A) \longrightarrow y_A^* = 0.75\,.\,x_A$$

$$0.75 \times 0.9 = 0.675$$

$$N_A = 0.019\,(0.675 - 0.45)$$

$$= 4.2 \times 10^{-3} \text{ mole/m}^2\text{. s}$$

DATE / / OBJECT

2

$$N_A = K_y (y_{A_i} - y_A)$$

$$4.2 \times 10^{-3} = 0.02716 (y_{A_i} - 0.45)$$

$$y_{A_i} = 0.607$$

3

$$\frac{1}{K_{oy}} = \frac{1}{K_y} + \frac{H \rightarrow m}{K_L}$$

$$\frac{1}{0.019} = \frac{1}{0.02716} + \frac{0.75}{K_L}$$

$$K_L = 0.0476$$

$$\frac{1}{K_{oL}} = \frac{1}{H \cdot K_y} + \frac{1}{K_L} = \frac{1}{0.75 \times 0.02716} + \frac{1}{0.0476}$$

$$= 0.0142 \ \text{kmol/s.m}^2$$

- special case in : diffusion.

Diffusion in a tube with change in path length.

$$t = \frac{\rho_A}{M.wt(A)} \left[\frac{R.T\,(P_{BLm})}{P_T \cdot D_{AB} \cdot (P_{A_1} - P_{A_2})} \right] \int_{Z=Z_0}^{Z=Z_f} Z * dZ$$

$$P_{BLm} = (1 - P_{ALm}) = \frac{(1-P_{A_2}) - (1-P_{A_1})}{\ln \frac{1-P_{A_2}}{1-P_{A_1}}}$$

$Z=0$	$Z=Z_2$	$Z=Z_f$
$t=0$	$t_1=t_2$	$t=t_f$

ex) A small diameter tube closed at one end was filled aceton to 18 mm of the top at 290 K and 99.7 Kpa with gental stream of air belowing across the top. after 15 Ksec the liquid level had filling to 27.5 mm, the vapor pressure of Aceton 21.95 Kpa. find the diffusivity?

Sol)

$T = 290$, $P_t = 99.75$ Kpa , $t = 15$ Ksec

$Z_f = 27.5$ mm , $P_{A_1} = 21.95$ Kpa , $D_{AB} = ?$

$\rho = 790$ kg/m³ , $P_{A_2} = 0$

$$t = \frac{\rho_A}{Mwt_{(A)}} \left[\frac{R \cdot T \, (P_{BLm})}{P_T \, D_{AB} \, (P_{A_1} - P_{A_2})} \right] \left[\frac{Z_f^2}{2} - \frac{Z_o^2}{2} \right]$$

$$P_{BLm} = \frac{P_{B_2} - P_{B_1}}{\ln \frac{P_{B_2}}{P_{B_1}}} = 88.321$$

$$D_{AB} = \frac{790}{580} \left[\frac{8.314 \times 290 \times 88.321}{99.75 \times 15000 \times (21.95 - 0)} \right] \left[\frac{0.0275^2}{2} - \frac{0.018^2}{2} \right]$$

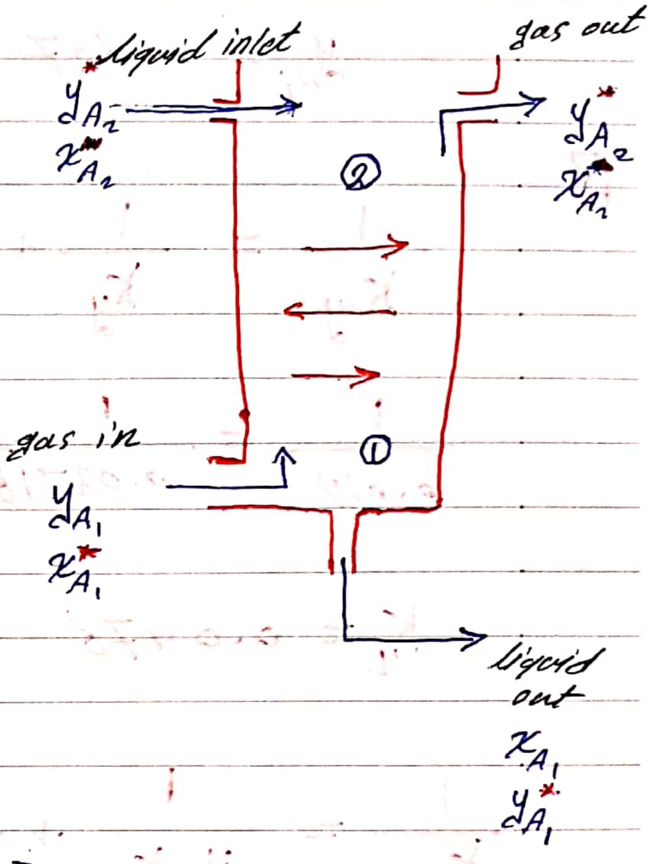
$$= 1.9 \times 10^{-5} \ m^2/s$$

DATE / / OBJECT

The wetted wall column

عمود بجدار مبلل

- mass transfer



$$\boxed{W_A = G\left[y_{A_1} - y_{A_2}\right]}$$

total mole rate

$$\boxed{W_A = L\left(x_{A_1} - x_{A_2}\right)}$$

$$\bar{N}_A = K_{oG} A\left[P_A - P_A^*\right]$$

or

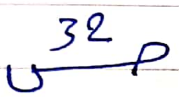
$$= K_{oy} A\left[y_A - y_A^*\right]$$

$$\bar{W}_A = K_{oy} \cdot A \; \Delta P_{LM}$$

$$W_A = K_{oy} \; \Delta P_{LM}$$

where :-
$$\Delta P_1 = P_{A_1} - P_{A_1}^*$$
$$\Delta P_2 = P_{A_2} - P_{A_2}^*$$

$$\Delta P_{Lm} = \frac{\Delta P_1 - \Delta P_2}{\ln \frac{\Delta P_1}{\Delta P_2}}$$

ex) 

$$A = \pi d L$$

$$A = \pi d L$$

$$\overline{W}_A = K_{oG} \, A \, \Delta y_{Lm}$$

$$\Delta y_1 = y_{A_1} - y_{A_1}^* \quad , \quad y_{A_1}^* = H \, x_{A_1}$$

$$\Delta y_2 = y_{A_2} - y_{A_2}^* \quad , \quad y_{A_2}^* = H \, x_{A_2}$$

$$\Delta y_{Lm} = \frac{\Delta y_1 - \Delta y_2}{\ln \frac{\Delta y_1}{\Delta y_2}}$$

Example: A wetted wall column is used to absorbed NH_3 by water from 6 vol.% in air. The gas flow rate is 1.2 kmol/min at 1 atm and 20°C. Calculate the overall mass transfer coefficient. The data given are:

- The water flow rate to gas flow rate ratio is 1.4.
- The outlet gas concentration is 1.5 vol.%.
- The column height is 100 cm.
- The column diameter is 2 cm.
- Henry's constant is 1.3.

Solution:

$$\bar{W}_A = G\left(y_{A_1} - y_{A_2}\right) = 1.2\,(0.06 - 0.015) = 0.054\ \frac{\text{kmol}}{\text{min}}$$

$$\bar{W}_A = 9 * 10^{-4}\ \frac{\text{kmol}}{\text{s}}$$

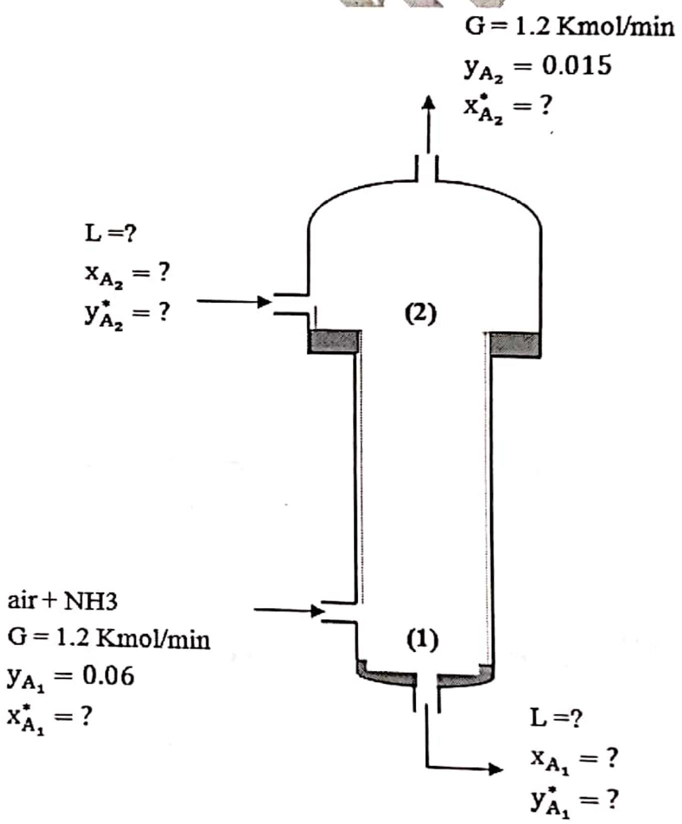
$$A = \pi dL = (3.14)\,(2*10^{-2})\,(1)$$

$$A = 0.06283\ m^2$$

$$\Delta y_{Lm} = \frac{\Delta y_1 - \Delta y_2}{\ln\left[\frac{\Delta y_1}{\Delta y_2}\right]}$$

$$\Delta y_1 = y_{A_1} - y^*_{A_1}$$

$$\Delta y_2 = y_{A_2} - y^*_{A_2}$$



To find (x_{A_1})

$$G\left(y_{A_1} - y_{A_2}\right) = L\left(x_{A_1} - x_{A_2}\right)$$

$$x_{A_1} = \frac{G}{L}\left(y_{A_1} - y_{A_2}\right) + x_{A_2}$$

$$x_{A_1} = \frac{1}{1.4}(0.06 - 0.015) + 0$$

$$x_{A_1} = 0.321$$

$$y^*_{A_1} = Hx_{A_1} = 1.3 * 0.0321 = 0.04173$$

$$y^*_{A_2} = Hx_{A_2} = 1.3 * 0 = 0$$

$\boxed{Y^* = Hx}$

$$\Delta y_1 = y_{A_1} - y^*_{A_1} = 0.06 - 0.04173 = 0.01827$$

$$\Delta y_2 = y_{A_2} - y^*_{A_2} = 0.015 - 0 = 0.015$$

$$\Delta y_{Lm} = \frac{0.01827 - 0.015}{\ln\left[\frac{0.01827}{0.015}\right]} = 0.0165$$

$$\overline{W}_A = K_{OG} \,.\, A \,.\, \Delta y_{Lm}$$

$$K_{OG} = \frac{\overline{W}_A}{A \,.\, \Delta y_{Lm}} = \frac{9 * 10^{-4}}{(0.06283)(0.0165)} = 0.868 \ \frac{\text{kmol}}{\text{m}^2 . s}$$

proplems in J.k

5.1.1

$$J_{AB} = \frac{D_{AB}(P_{A_1} - P_{A_2})}{R.T\,(\Delta Z)} = 5.52 \times 10^{-5}$$

$$J_{BA} = -J_{AB} = -5.52 \times 10^{-5}$$

5.2.1

@ $$J_{AZ} = \frac{0.687 \times 10^{-4}\,(0.06 - 0.02)}{82.06 \times 298 \times (0.1 - 0)}$$

$$= 1.124 \times 10^{-6}$$

b) -1.124×10^{-6}

c) At $Z = 0.05$

$$P_A = \frac{0.06 + 0.02}{2} = 0.04\ atm$$

another way

$$\because J_{AZ} = \frac{0.687 \times 10^{-4}\,(0.06 - P_A)}{82.06\,(298)\,(0.05 - 0)}$$

$$\therefore P_A = 0.04\ atm$$

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5.2.7

ⓐ

$$D_{AB} = 2.05 \times 10^{-5}$$

$$N_A = \frac{2.05 \times 10^{-5} (0.0152 - 0.0132)}{82.06 \times 10^{-3} \times 298 \times 0.11}$$

$$= 7.02 \times 10^{-7}$$

b) at $T = 200°C$, $473 K$

$$D_{AB} = 2.05 \times 10^{-5} \left(\frac{473}{298}\right)^{1.75} = 4.6 \times 10^{-5}$$

$$N_A = 9.92 \times 10^{-7}$$

notes :- في بعض الاحيان يطلب في السؤال سرعة المكون (V_i)

$$V_i = \frac{J_i}{C_i}$$ اذا مكون واحد

moler total diffisivity $$V_m = \frac{N_A}{C}$$

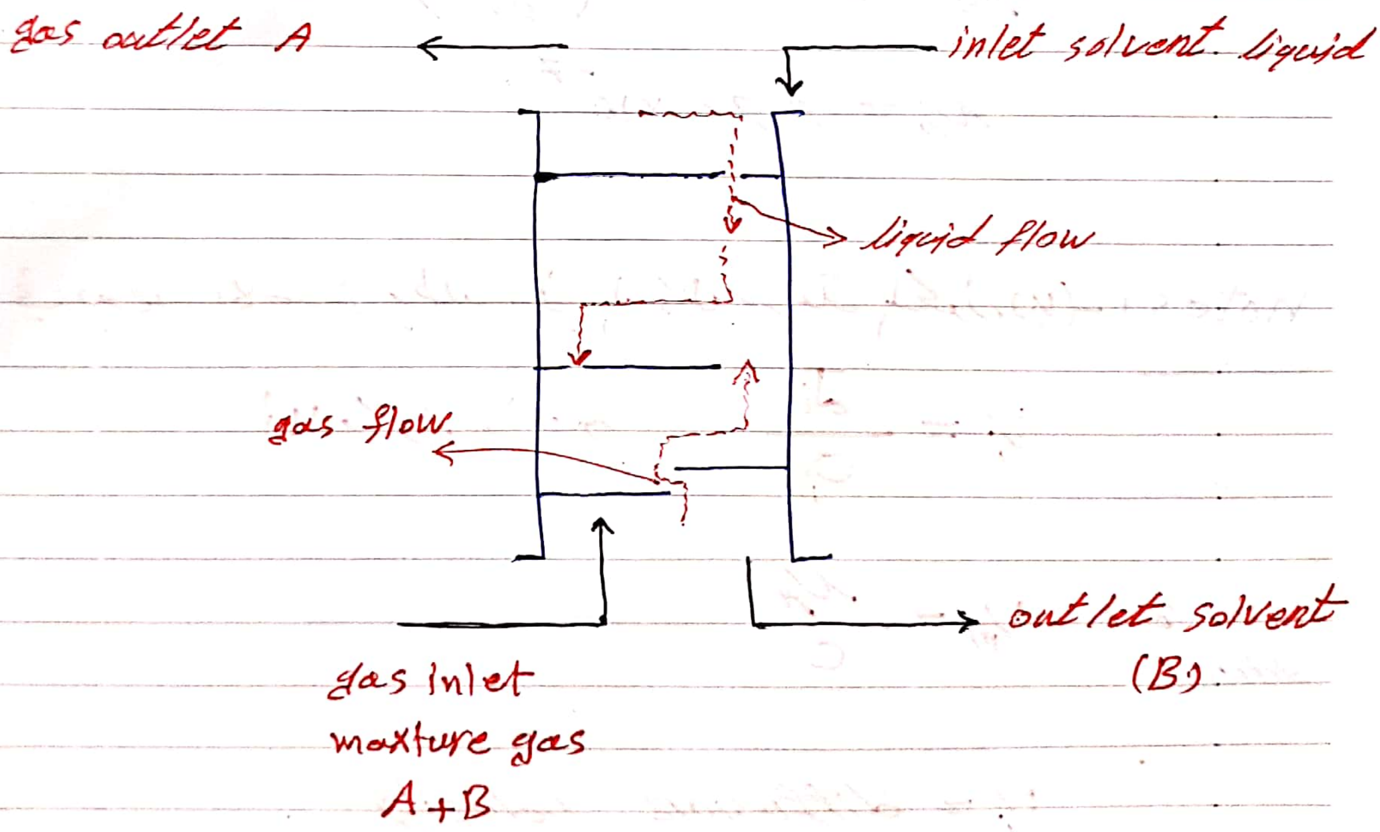
V_i = diffusion velocity

* Chapter two

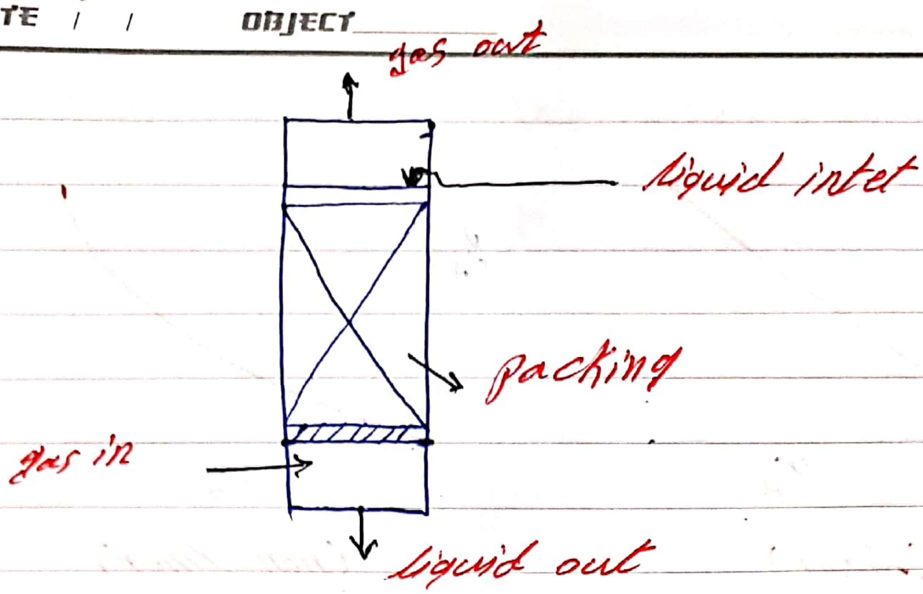
- Absorption of gases :-

① Tray Tower برج الصواني

② packed Tower برج الحشوات



(Tray Tower)



(packed Tower)

page (4) Types of packing

page (5) equilibrium Relation

no. ideal system
Henry's Law

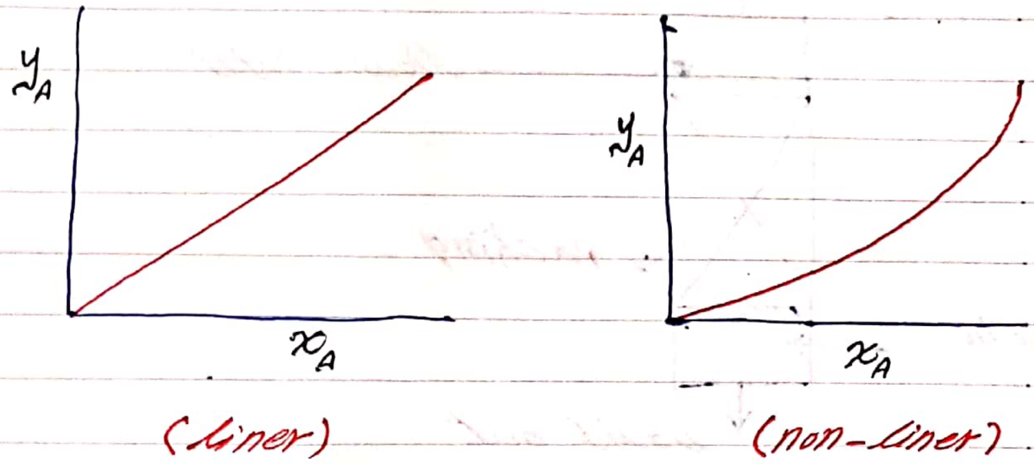
$$P_A = H \cdot x$$

$$y_A = m \cdot x_A$$

ideal system
Roult's Law

$$P_A = P_A^{\circ} \cdot x$$

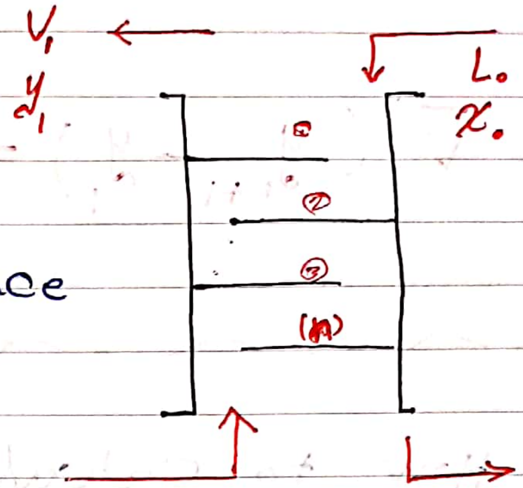
$$y_A = m \cdot x_A$$



$$\underset{\text{ratio}}{Y_A} = \frac{y_A}{1-y_A} \quad , \quad \underset{\text{ratio}}{X_A} = \frac{x_A}{1-x_A}$$

Y_A , X_A , mole ratio gas and liquid.

- Deriviation the operating line for countecurrent contact stage.



- overall material Balance (m.B)

- $L_0 + V_{n+1} = V_n + L_n = m$ --- (1)

- m.B for (A) component:-

- $L_0 \, x_{A_0} + V_{n+1} \cdot y_{n+1} = V_n \cdot y_n + L_n \, x_n$ --- (2)

- m.B for on (n) stage:-

$$L_0 \, x_{A_0} + V_{n+1} \cdot y_{n+1} = V_1 \, y_1 + L_n \cdot x_n$$

$$\boxed{y_{n+1} = \underbrace{\frac{L_n}{V_{n+1}}}_{\text{slope}} \cdot x_n + \frac{V_1 y_1 - L_0 x_0}{V_{n+1}}}$$

* operating line eq.

- if flow rate (V, L) for gas and L are constant

average flow rate $\bar{V}(y_{n+1} - y_1) = L'(x_n - x_o)$

- How to calculate the stages numb.

Draw eq. (Data) $\longrightarrow$ Find $\theta = \tan^{-1}$ slope

$$slop = \frac{L_n}{V_{n+1}}$$

find intercept $\left(\frac{V_1 y_1 - L_0 y_0}{V_{n+1}}\right)$

find Toppoint (x_0, y_1), Bottompoint (x_n, y_{n+1})

Draw a horizantal line and vertical line

Count the stage number

find actual no. $= \dfrac{\text{Theortical no.}}{\text{كفاءة } \eta}$

How to calculate Tower Height

packed tower

$Z = HOG \times NOG$

tray tower

$H = H \cdot N$

$(0.3 - 0.7)\ m$

NOG = The number of transfer unit

N = Tray no

Tower height = height of transfer unit * no. of transfer unit

$Z = HTU \times NTU$

ارتفاع الغاز بالبرج   عدد الصفائح

ارتفاع البرج $Z = HOG \times NOG$ → gas

ارتفاع السائل بالبرج

$Z = HOL \times NOL$ → liquid

NOL, NOG → لها أربع طرق

$$\boxed{N_{OL} = N_{OG} * \phi}$$

عند وجود أحدهم ..

$$\phi = m \frac{V_m}{L_m}$$

m = slope of equilibrium curve which it straight line with dilute mixture.

V_m = molar flow rate of gas $= \frac{V}{M.wt}$

L_m = molar flow rate of liquid $= \frac{L}{M.wt}$

or

$$\boxed{N_{OG} = \frac{1}{1-\phi} \ln \left[(1-\phi)\frac{Y_1}{Y_2} + \phi \right]}$$

((Kersmar eq.))

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DATE / / OBJECT $(y_{n+1} < 10\%)$

$\boxed{\cancel{y_{n+1} > 10\%}}$

NOG

- Draw
- $\frac{y_1 - y_2}{(Y - Y_e)L_m}$
- Kresmer
- Algebric

Draw

* مطلوب معرفة x_n ، x_0 ، y_1 ، y_{n+1}

أذا كان ثلاثة معلومة نحسب الرابعة من المعادلة :-

$$G_m (y_{n+1} - y_1) = L_m (X_n - x_0)$$

* ① تعطى نسبة مثل $(x = 0.5)$ نأخذ لها هيكل مناسب

مثل $(0.5 \longleftarrow 0)$

② نحسب y من $y = mx$

x	y
0	✓
0.1	✓
0.2	✓
0.3	✓
0.4	✓
0.5	✓

③ نحدد (bottom , Top)

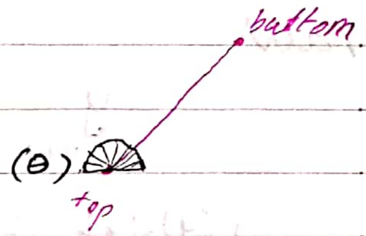
Top (x_0 , y_1)

bottom (x_n , y_{n+1})

④ نحدد الميل

$$\text{slop} = \frac{L_n}{V_{n+1}}$$

$$\theta = \tan^{-1}\text{slop} \Rightarrow \theta$$



⑤ من هذا الرسم نعرف عدد الصواني النظرية وعشوما يطلب الحقيقي ا-

$$\text{actual} = \frac{\text{tho.}}{\eta}$$

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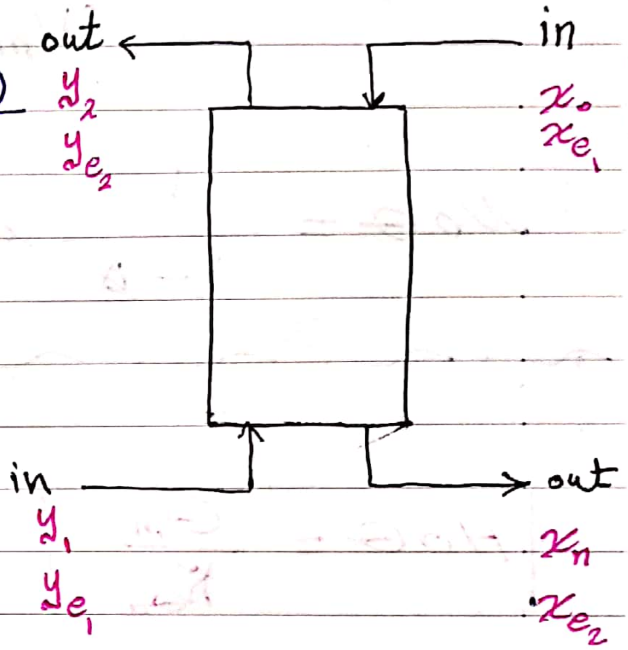
* $$NOG = \frac{y_1 - y_2}{(y - y_e)_{Lm}}$$

① $$(y - y_e)_{Lm} = \frac{(y_1 - y_{e_1}) - (y_2 - y_{e_2})}{\ln \frac{y_1 - y_{e_1}}{y_2 - y_{e_2}}}$$



② $$\boxed{y_{e_1} = m \times x_{e_2}}$$

or

$$y_{e_1} = m \times x_n$$

③ $$\boxed{y_{e_2} = m \times x_{e_1}}$$

or

$$y_{e_2} = m \times x_o$$

* Kressmer

$$\phi = m \frac{L_m}{V_m} \Rightarrow m \cdot \frac{V_m}{L_m}$$

$$NOG = \frac{1}{1-\phi} \ln \left[(1-\phi) \frac{Y_{1\,in\,(bottom)}}{Y_{2\,out\,(Top)}} + \phi \right]$$

$$\boxed{HOG = \frac{G_m}{K_{Ga}}}$$

أرتفاع الغاز بالبرج

* ملاحظة :- أذا ذكر في السؤال كلمة (recovered) نأخذها تعتبر كفاءة (η)

EX -1 $U^{18}P$:-

$x_\circ = 0$

$L_{actual} = 1.75\, L_{min}$

(minimum)

$$\begin{cases} G_{min}(y_1 - Y_2) = L_{min}(x_n - \cancel{x_\circ}) \\ \left(\frac{L}{G}\right)_{min} = \frac{Y_1 - Y_2}{x_1} \end{cases}$$

جزء

$$Y_1 = m \cdot x_1 \Rightarrow x_1 = \frac{Y_1}{m}$$

$$\left(\frac{L}{G}\right)_{min} = \frac{Y_1 - Y_2}{Y_1/m}$$

$$\left(\frac{L}{G}\right)_{min} = m\left(1 - \frac{Y_2}{Y_1}\right)$$

$$Y_2 = (1 - 0.99) \times y_1 \Rightarrow Y_2 = 0.01\, Y_1$$

$$\left(\frac{L}{G}\right)_{min} = m\left(1 - \frac{0.01\cancel{Y_1}}{\cancel{Y_1}}\right)$$

$$= 0.99\, m$$

$$\theta = m\left(\frac{G}{L}\right)_{act}$$

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$$\left(\frac{L}{G}\right)_{act} = 1.75 \times 0.99\, m$$

$$= 1.73\, m$$

$$\phi = \cancel{m} \times \frac{1}{1.73\, \cancel{m}} = 0.57$$

$$NOG = \frac{1}{1-\phi} \ln\left[(1-\phi)\frac{Y_1}{Y_2} + \phi\right]$$

$$= \frac{1}{1-0.57} \ln\left[(1-0.57)\frac{\cancel{Y_1}}{0.01\cancel{y_1}} + 0.57\right]$$

$$= 2.325 \ln 43.57$$

$$= 8.8$$

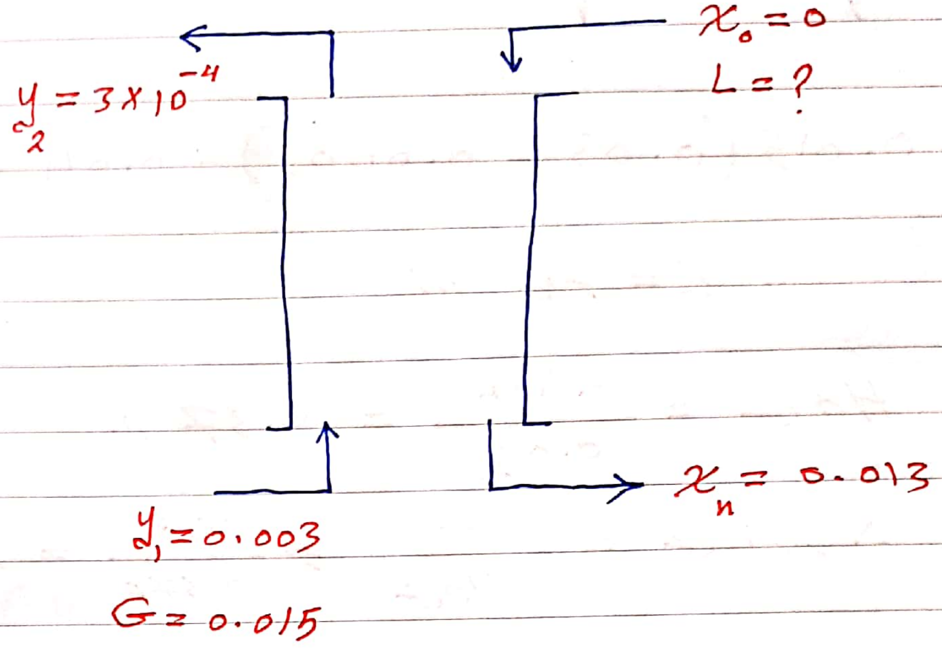
$$Z = HOG * NOG$$

$$= 1 \times 8.8$$

$$= 8.8$$

DATE / / OBJECT

Solution of example ((12.4))



$Z = HOG * NOG$

~~Kerson~~ Kersmon " M.B

$$G(y_1 - y_2) = K_{Ga}(y - y_e)_{Lm} * Z$$

$$(y - y_e)_{Lm} = \frac{(y_1 - y_{e_1}) - (y_2 - y_{e_2})}{\ln \frac{(y_1 - y_{e_1})}{(y_2 - y_{e_2})}}$$

$$= \frac{(0.003 - 0.026) - (0.0003 - 0)}{\ln \frac{(0.003 - 0.026)}{(0.0003 - 0)}} = 0.00143$$

$y_{e_2} = m \cdot x_{e_2} \Rightarrow 2 \times 0 = 0$

$y_{e_1} = m \cdot x_{e_1} \Rightarrow 2 \times 0.013 = 0.026$

$0.015\,(0.03 - 0.0003) = 0.04\,(0.00143) * Z$

$\therefore Z = 7.8\ m$

$HOG = \frac{0.015}{0.04} = 0.37\ m$

$\therefore NOG = \frac{Z}{HOG} \Rightarrow \frac{7.8}{0.375} = 21$

* إذا كان التركيز $(y_{n+1} > 10\%)$
هنا نشتغل على (ratio)

* $Y = \frac{y_1}{1-y_1}$, $Y_{n+1} = \frac{y_{n+1}}{1-y_{n+1}}$

* $X_0 = \frac{x_0}{1-x_0}$, $X_n = \frac{x_n}{1-x_n}$

* في هذه الحالات ((non-liner , delute , phase gas))
نستخدم هذا القانون :-

$$Z = \frac{\overline{G}_s}{K_{OG}.a} \times \frac{y_1 - y_2}{(y - y_e)_{LM}}$$

$$\Downarrow \qquad \Downarrow$$

- $Z = HOG * NOG$

- $$(y - y_e) = \frac{(y_1 - y_{e_1}) - (y_2 - y_{e_2})}{\ln \frac{(y_1 - y_{e_1})}{(y_2 - y_{e_2})}}$$

* phase liquid :

$$Z = \frac{\bar{L}_s}{K_{oL}.a} \times \frac{x_2 - x_1}{(x - x_e)_{Lm}}$$

$$\Downarrow \qquad \Downarrow$$

- $Z = H_{oL} \times N_{oL}$

- $(x - x_e)_{Lm} = \dfrac{(x_2 - x_{e_2}) - (x_1 - x_{e_1})}{\ln \dfrac{x_2 - x_{e_2}}{x_1 - x_{e_1}}}$

ملاحظة -1

$G = \dfrac{kg}{m^2 \cdot s}$ mass flow rate

$\bar{G} = \dfrac{kmol}{m^2 \cdot s}$ molar flow rate

$\bar{G}_s = \bar{G}(1 - y_1^{in})$

$\bar{L}_s = \bar{L}(1 - x_0^{in})$

* اذا كان السؤال (non-liner, ~~dilute~~ non-dilute)
نستخدم طريقة الجداول :-

$$Z = \underbrace{\frac{\bar{G}_s}{K_{OG}.a}}_{HOG} \times \underbrace{\int_{Y_2}^{Y_1} \frac{dY}{(Y-Y_e)_{Lm}}}_{NOG} \quad ((\text{for gas}))$$

HOG يستخرج مباشرة
NOG يستخرج من الجداول

* مع العلم تحويل كل ($y \leftarrow Y_{ratio}$)

① نرسم الكيرف من معادلة التوازن مثلا ($Y_e = 0.8X$)

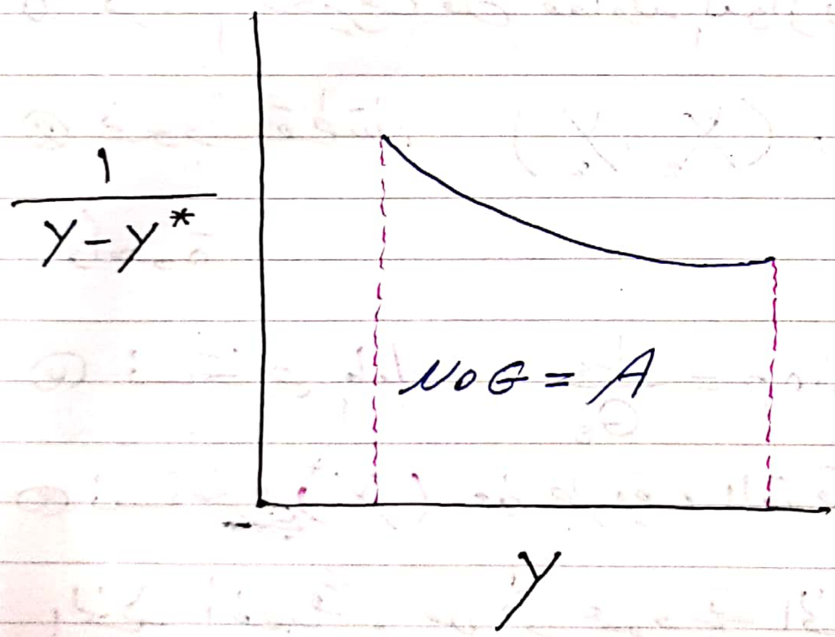
② نحدد نقطتين $(X_1, Y_1), (X_2, Y_2)$ أو نقطة واحدة.

③ نستخرج الميل $slop = \frac{L_s}{G_s}$ ثم $\theta = \tan^{-1} slop$

④ نستخرج (Y^*) عن طريق التسقيط من النقطة التي الخط أفقياً ومن ثم عمودية الى الكيرف ومن ثم أفقياً للمحور لقراءة (Y^*)

٥ ثم حساب (NOG) عن طريق الجدول الآتي

$\frac{1}{(Y-Y^*)}$	Y^*	Y	
f_0 فردي	من الرسم	من الداخل	(Y_{n+1})
f_1 فردي			
f_2 زوجي			
f_3 فردي			
f_n لا يدخل بالقانون الزوجي أو الفردي		الخارجة	Y_1



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$$\boxed{NOG = \frac{h}{3}\left[f_0 + f_n + 2\sum f_{even} + 4\sum f_{odd}\right]}$$

$$h = \frac{\overset{in}{Y_1} - \overset{out}{Y_2}}{n} \quad , \quad n = \text{عدد القيم بالجدول}$$

* for liquid

$$Z = \underbrace{\frac{L_s}{K_{OL} \cdot a}}_{\text{مباشرة}} \times \underbrace{\int_{x_2}^{x_1} \frac{dx}{(X^* - X)}}_{\text{بالرسم والجدول}}$$

⊛ مع العلم تحويل $(X_{ratio} \leftarrow x)$

① نرسم المنحني حسب المعادلة المعطاة.

② نحدد النقطتين (X_2, Y_2) و (X_1, Y_1) أو أحدهما.

③ نستخرج slop

$$slop = \frac{L_s}{G_s}$$

$$\theta = \tan^{-1} slop$$

④ نستخرج (X^*) عن طريق نسقط (X_1) عمودياً الى الخط ثم أفقياً للمنحني ومن ثم عمودياً على محور x وبعدها نقرأ قيمة (X^*).

⑤ حساب (NOL) من الاتي :....

X	X^*	$\frac{1}{(X^* - X)}$
من الداخل $(x_\circ)$	من الرسم	f_0
		فردي f_1
~~[illegible]~~ فرض		زوجي f_2
		فردي f_3
		زوجي f_4
الخارج (x_n)		لايدخل f_n

$$\boxed{NOL = \frac{h}{3}\left[f_0 + f_n + 2\sum f_{even} + 4\sum f_{odd}\right]}$$

Simpson's rule, قاعدة

* في حالة أعطى تركيز الداخل أكبر من 10%

((non-dilute , conc.))

- لا نستخدم الطرق السابقة في الحل بل نستخدم الطريقة التالية :-

$$Z = HOG * NOG$$

$$HOG = \frac{\bar{G}}{K_{OG} \cdot a}$$

$$NOG = \int_{Y_1}^{Y_2} \frac{(1+Y)(1+Y_i)}{(Y-Y_i)}$$

in

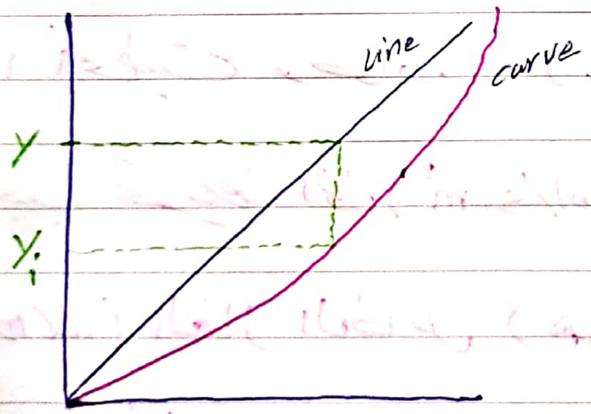
	Y	Y_i	$Y-Y_i$	$(1+Y)(1+Y_i)/(Y-Y_i)$
Y_{n+1}	من الداخل	من الرسم	"	
فرضيات				
Y_1	الى الخارج			

مثلاً / $y = mx$ معادلة نقوم بفرض قيم للـ x
على ضوء قيم (Y) من الداخل للخارج ونحسب

y	x
—	—
—	—
—	—
—	—

بعدها نرسم الكيرف ونحدد نقطة Top , bottom.

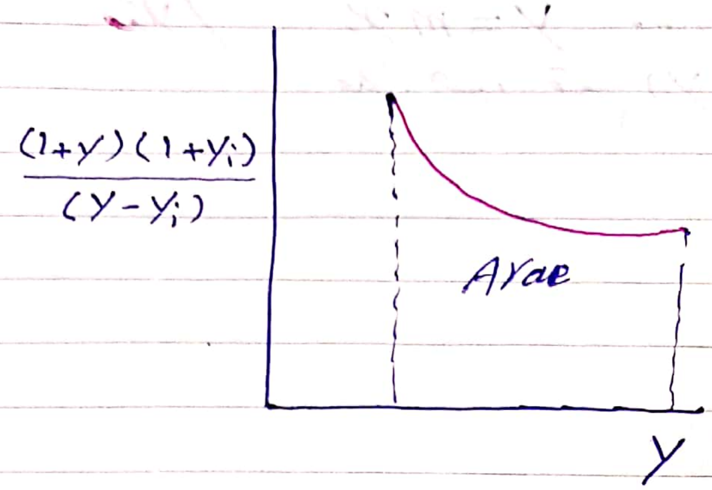
ثم بتسقيط قيم Y على الخط (line) أفقياً ومن ثم
عمودياً على ~~الكيرف~~ الكيرف وبعدها نقرأ قيم (Y_1)



- لإيجاد قيمة (NOG) وهي $\int_{Y_1}^{Y_2} \frac{(1+Y)(1+Y_1)}{(Y-Y_1)}$

من خلال المساحة تحت المنحنى

Aarea = NOG



- ملاحظات :

* في بعض الاسئلة يعطي Data (p^*) منقسمة على (P_T) لإيجاد (y)

* إذا أعطيت وحدات (G, L) للغاز الحامل ($kg/s.m^2$) فيجب تحويلها الى ($kmol/s.m^2$) وذلك بتقسيمها على (MW) الغاز الحامل (هواء) أو الماء بالنسبة (L)

* اذا أعطيت نسبة مشتركة مثلا (10% مشتركة أمونيا وهواء) نستخدم القانون التالي لأستخراج قيمة (Y_{n+1}) ونقارنها اذا كانت أكبر او أصغر من 10%

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$$wt\% = \frac{M.wt \times y_{n+1}}{M.wt \times y_{n+1} + M.wt \times (1-y_{n+1})}$$

(وزنی)

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Ex) ammonia is removed from (10%) air mixture using fresh water in Pack Tower so (99.9%) of ammonia is removed. what is the required height of the tower if inter gas (1.2 Kg/m²s). water rate (0.94 Kg/m²s) $K_Ga = 8*10^{-4}$ Kmol/m².s

sol)

$$wt\% = \frac{Mwt * y_1}{Mwt \times y_1 + Mwt_{air} * (1 - y_1)}$$

أمونيا

$$0.1 = \frac{17 y_1}{17 y_1 + (29 - 29 y_1)}$$

$$0.1 = \frac{17 y_1}{29 - 12 y_1}$$

$$17 y_1 = 2.9 - 1.2 y_1$$

$$y_1 = 0.159$$

$$y_1 = 15.9\%$$ non-dilute

$$y_2 = (1 - 0.999) \times 15.9\% = 0.000159$$

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$$Y_1 = \frac{0.159}{1-0.159} = 0.189$$

$$Y_2 = \frac{0.000159}{1-0.000159} = 0.000159$$

$$G = \frac{1.2}{29} = 0.0413 \text{ kmol}/m^2.s$$

$$L = \frac{0.94}{18} = 0.0522 \text{ kmol}/m^2.s$$

$$G(y_1 - y_2) = L(x_1 - x_0)$$

$$x_1 = 0.1256$$

$$X_1 = \frac{0.1256}{1-0.1256} = 0.1436$$

Top (0, 0.000159)

bottom (0.1436, 0.189)

* column efficiency :-

1- overall column efficiency (E_c)

$$E_c = \frac{N_{th}}{N_{act}}$$

N_{th} عدد الصفائح النظرية

N_{act} عدد الصفائح الحقيقية

$N_{act} > N_{th}$

$E_c = 100\%$ $\quad N_{act} = N_{th}$

$$\boxed{Z = N_{act} * \text{tray spacing}}$$

2- plate efficience (Em) :-

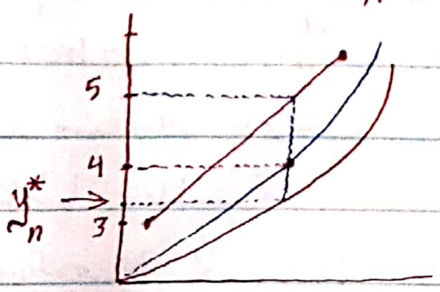
Em = Murphree plate efficience.

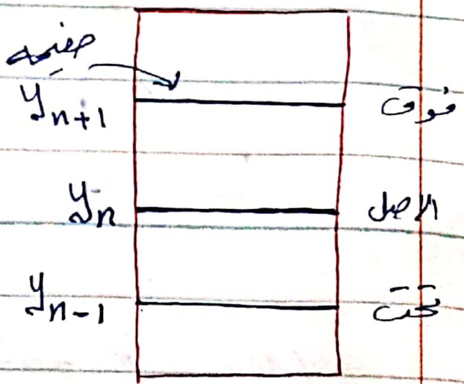
$\boxed{a.}$ plate efficience based on gas phase.

$$E_{mv} = \frac{y_n - y_{n+1}}{y_n - y_n^*} = \frac{\overline{bc}}{\overline{ac}}$$

$y = 5$

$y_{n+1} = 4$

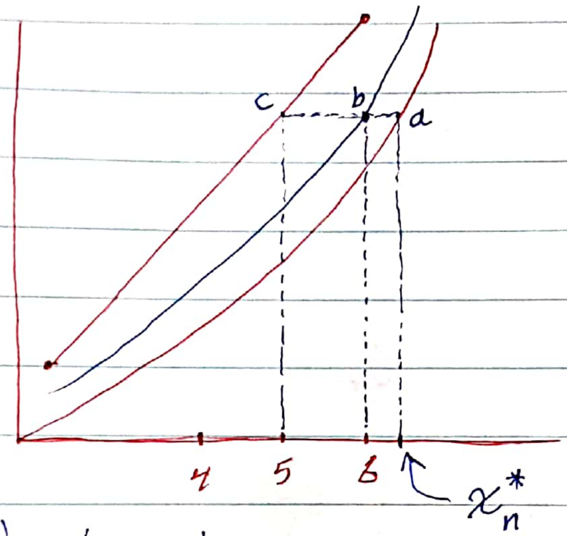




②

$\boxed{b}$ plate efficiency based on liquid phase

$$E_{mL} = \frac{x_n - x_{n-1}}{x_n - x_n^*} = \frac{\overline{bc}}{\overline{ac}}$$



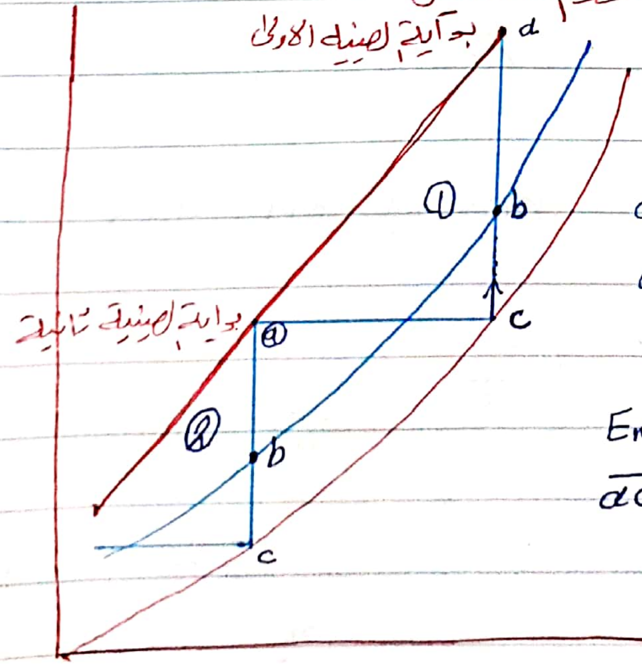
$x_n = 5$

$x_{n+1} = 4$

$x_{n-1} = 6$

* لإيجاد عدد الصواني الحقيقية ((N_{act})) فيما لو أعطيت (E_{mv}, E_{mL})

مثال توضيحي :- من معلوماتنا السابقة د ((Draw)) رسمنا صواني نظرية وخط التشغيل



لو بينا $E_{mv} = 80\%$ ((gas))

- نقيس المسافة بالمسطرة حسب تقسيمات الرسم (محور y) من ((C)) الى ((d))

- نطبق القانون $E_{mv} = \frac{\overline{bc}}{\overline{dc}}$

منجد ((bc)) وتكون أقل من $\overline{dc}$ ثم نحدد مسافتها بالرسم.

- ونفس الخطوات بالنسبة للصينية لبعدها ثم أوصل بين نقاط ((b)) لنجد (New eqm)

- إيجاد عدد N_{act} نفس طرقتنا السابقة ولكن بين خط التشغيل و New eqm

⊛ Calculation of the Height equivalent plate (HETP)

- $HETP = HOG * \frac{\ln \phi}{1-\phi}$ ⇐ «tray spacing»

$\phi = \frac{mG}{L}$

$\boxed{Z = N * HETP}$ tray tower

نقي   trays tower

Example (2): A mixture of ammonia and air is scrubbed in a plate column with fresh water. If the ammonia concentration is reduced from 5% to 0.5% .Given that: $Y = 2X$.

a. Calculate the No. of theoretical plate and the tower height. Given that: $L = 0.65$ $Kg/m^2.s$ and $G = 0.4\ Kg/m^2.s$, $K_{OG}.a = 0.0008\ Kmol/m^3.s.kPa$

b. Calculate the No. of theoretical plate, given that: $\left(\frac{L}{G}\right) = 2\left(\frac{L}{G}\right)_{min}$.

c. Calculate $\left(\frac{L}{G}\right)$ if the actual No. of plates $= 12$, and the column efficiency $= 0.5$.

d. Calculate the theoretical and actual No. of plates, give that:

$\left(\frac{L}{G}\right) = 1.5\left(\frac{L}{G}\right)_{min}$ and $E_{mv} = 0.7$

e. Given the concentration of a gas in the two adjacent plates are 4% and 3.3%. Calculate E_{mv} and E_{ml} if $L = 0.65\ Kg/m^2.s$ and $G = 0.4\ Kg/m^2.s$.

Solution:

Since the inlet gas concentration is 5% then no need to convert the mole fraction to mole ratio:

Ex) 2 : ص 88

* plate colum

$y_1 = 0.05 < 0.1$ dilute

$y_2 = 0.005$ $\qquad$ $y = 2x$

Sol)

@ $N_{th} = ?$ $\qquad$ $Z = ?$

$L = 0.65 \frac{kg}{m^2 \cdot s}$, $G = 0.4 \frac{kg}{m^2 \cdot s}$, $K_{OG} \cdot a = 0.0008$ kmol/m³.s kpa

$$\bar{L} = \frac{0.65}{18} = 0.0361 \text{ kmol/m}^2\text{.s}$$

$$\bar{G} = \frac{0.4}{29} = 0.01379 \text{ kmol/m}^2\text{.s}$$

$$\bar{G}(y_1 - y_2) = \bar{L}(x_n - x_o)$$

$$0.01379(0.05 - 0.005) = 0.0361(x_n - 0)$$

$$x_n = 0.01718$$

Top $(0, 0.005)$, bottom $(0.01718, 0.05)$

$$H_{OG} = \frac{\bar{G}}{K_{OG} \cdot a \cdot kpa} = \frac{0.01379}{0.0008 \times 101.3} = 0.17 \text{ m}$$

$$HETP = H_{OG} * \frac{\ln \phi}{1 - \phi} = 0.19 \text{ m}$$

$$\phi = \frac{m \bar{G}}{\bar{L}} = \frac{2 \times 0.01379}{0.0361} = 0.7639$$

$N = 4 + 1 = 5$ plate

$Z = N * HETP$

$= 5 * 0.19 = 0.95\ m$

b) $N_{th} = ?$

$$\left(\frac{L}{G}\right)_{act} = 2\left(\frac{L}{G}\right)_{min}$$

$$\left(\frac{L}{G}\right)_{min} = m\left(1 - \frac{Y_2}{Y_1}\right)$$

$$= 2\left(1 - \frac{0.005}{0.05}\right) = 1.8$$

$$\left(\frac{L}{G}\right)_{act} = 2 \times 1.8 = 3.6$$

$$G(Y_1 - Y_2) = L(X_n - X_0)$$

$$\left(\frac{L}{G}\right) = \frac{Y_1 - Y_2}{X_n} \Rightarrow 3.6 = \frac{0.05 - 0.005}{X_n}$$

$$X_n = 0.0125$$

Top $(0, 0.005)$, bottom $(0.0125, 0.05)$

$N = 3$ plates

c) $\left(\frac{L}{G}\right)_{act}$, $N_{act} = 12$, $E_c = 0.5$

$$E_c = \frac{N_{th}}{N_{act}} \Rightarrow 0.5 = \frac{N_{th}}{12}$$

$$N_{th} = 6 \text{ plates}$$

$$\left(\frac{L}{G}\right)_{min} = \frac{\Delta y}{\Delta x} = \frac{0.051 - 0.005}{0.0205 - 0}$$

$$= 2.243$$

d) $N_{th} = ?$, $N_{act} = ?$

$$\left(\frac{L}{G}\right)_{act} = 1.5 \left(\frac{L}{G}\right)_{min}$$

$$\left(\frac{L}{G}\right)_{min} = 2\left(1 - \frac{0.005}{0.05}\right) = 1.8$$

$$\left(\frac{L}{G}\right)_{act} = 1.8 \times 1.5 = 2.7$$

$$\bar{G}(Y_1 - Y_2) = \bar{L}(x_n - x_o)$$

$$\left(\frac{L}{G}\right) = \frac{0.05 - 0.005}{x_n} \Rightarrow 2.7 = \frac{0.045}{x_n}$$

$$x_n = 0.0166$$

Top $(0, 0.005)$, bottom $(0.016, 0.05)$

$N_{th} = 4$ $\qquad N_{act} = 5.6$

e) $y_n = 0.04$, $y_{n+1} = 0.033$

· Top $(0, 0.005)$, bottom $(0.17, 0.05)$

من الرسم (($y_n^* = 0.0265$))

$$E_{mv} = \frac{y_n - y_{n+1}}{y_n - y_n^*} = \frac{0.04 - 0.033}{0.04 - 0.0265}$$

$$= 0.74$$

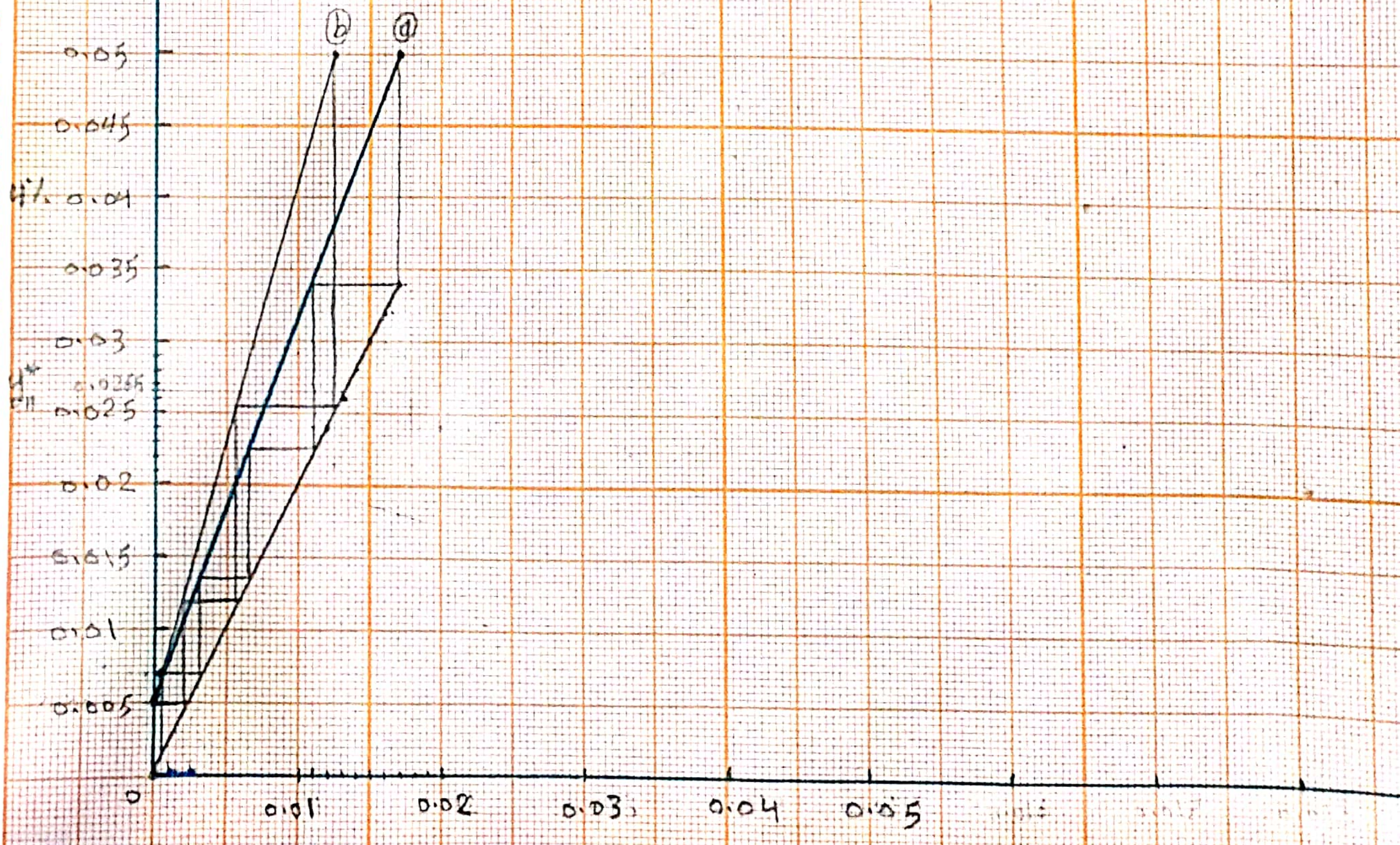
①

ⓐ ⓑ ⓔ حل / نقطة

line ⓐ

(Data

x	y
0	0
0.012	0.024
0.013	0.026
0.014	0.028
0.015	0.03
0.016	0.032
0.017	0.034



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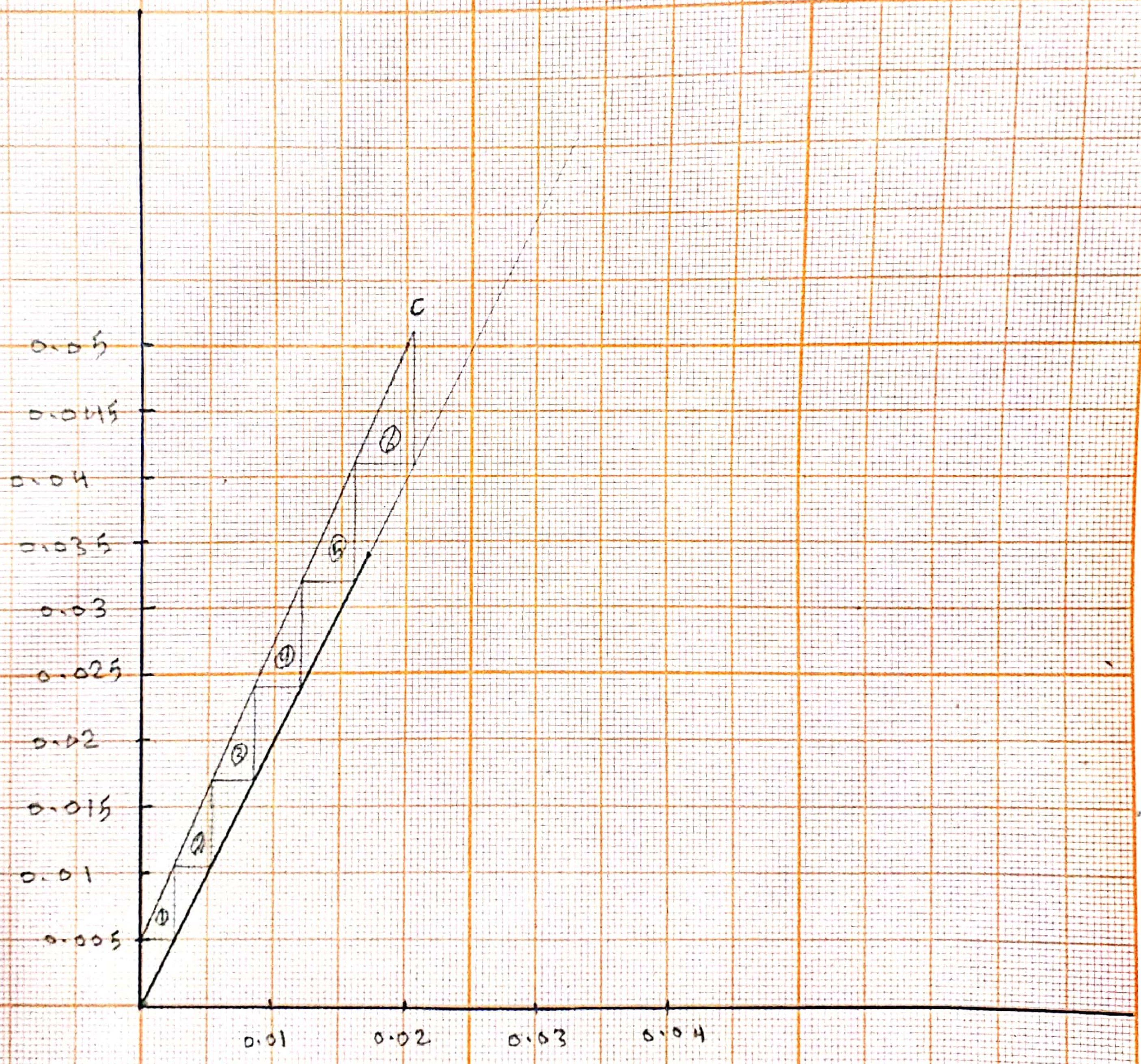
c)

$$\left(\frac{L}{G}\right)_{min} = \frac{\Delta y}{\Delta x}$$



D)

Top(0, 0.005)

bottom(0.016, 0.05)

$\overline{ac_1} = 0.018$

$\overline{ac_2} = 0.013$

$\overline{ac_3} = 0.009$

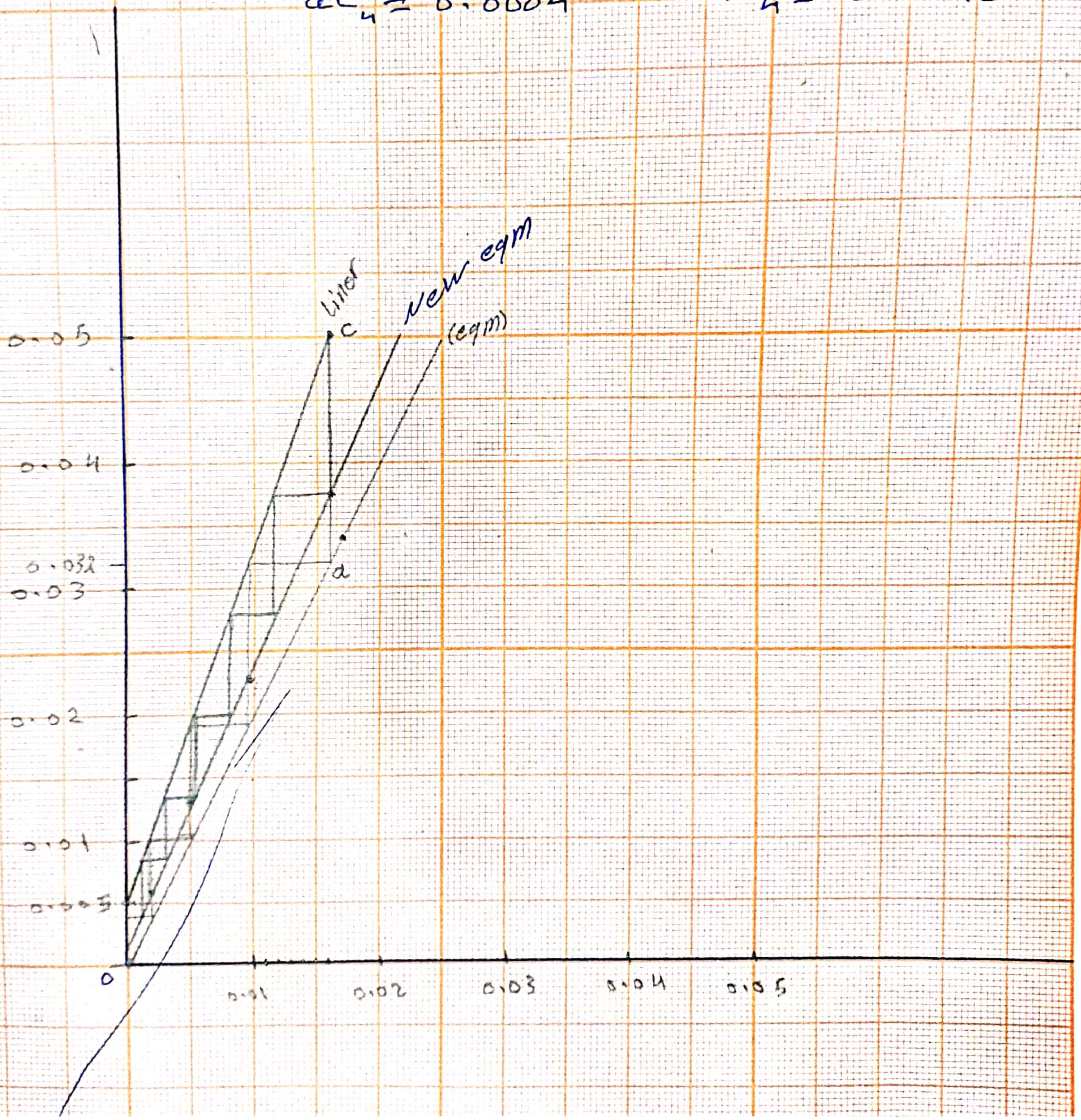
$\overline{ac_4} = 0.0064$

$\overline{bc_1} = 0.0126$

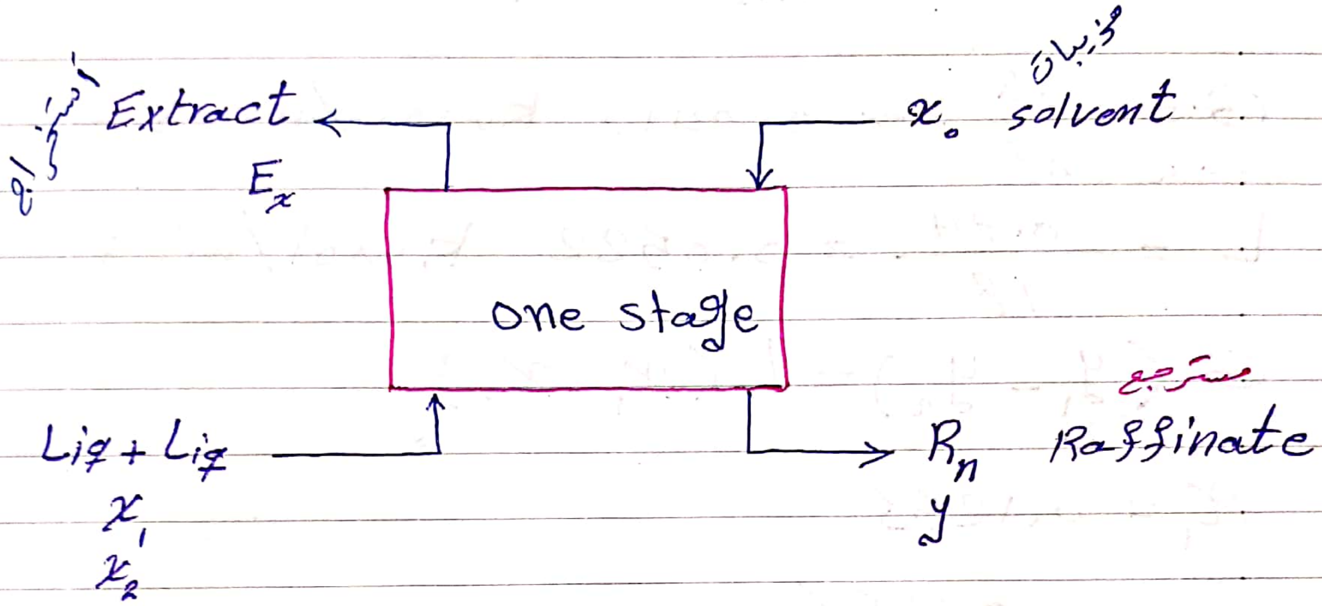
$\overline{bc_2} = 0.0091$

$\overline{bc_3} = 0.0063$

$\overline{bc_4} = 0.0048$



* Extractor :- «الاستخلاص»



$Y_{E,A}$ = conc. of A in extract

$x_{R,A}$ = conc. of A in Raffinate.

* cocurrent

* counter current

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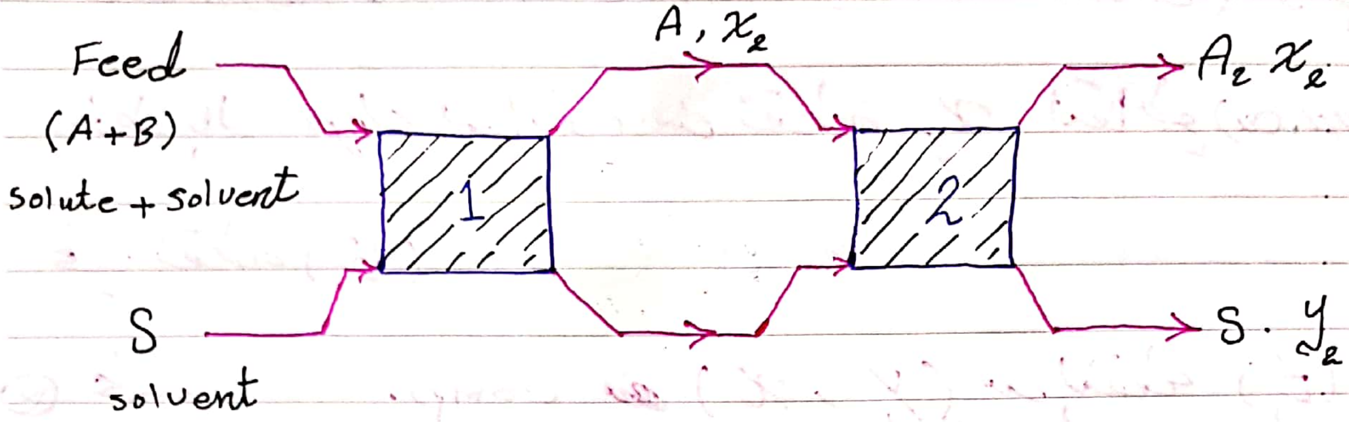


- لحساب عدد المراحل في أبراج الاستخلاص في حالة الجريان المتوالي (con current)

① أما نجد قيمة الـ (n) من القانون التالي

$$n = \frac{\log x_R / x_F}{\log \left[\frac{A}{A+Sm}\right]}$$

ويتم ذلك عندما يكون المعطى في السؤال تركيز الـ solute في آخر مرحلة أو نستخدم طريقة الرسم.

② نجد قيمة $\left(-\frac{A}{S}\right)$ والذي يمثل قيمة slop ومن slop نجد الزاوية نضع المنقلة على نقطة (x_F) بعد أن يتم رسم (equ. curve) بين تركيز solute في

sema
NOTEBOOK & STATIONERY

Raffinate وتركيز solute في (extract) نرسم

خط بالـ slop السابق من نقطة x_f ليتقاطع (equ.cu)

في نقطة (E_1)

② نحدد comp. (x_1 , y_1) من النقطة (E_1)

ونعوض قيم (x_1 , y_1) في معادلة $(m.B)$ لايجاد $\left(\frac{-A}{S}\right)_2$

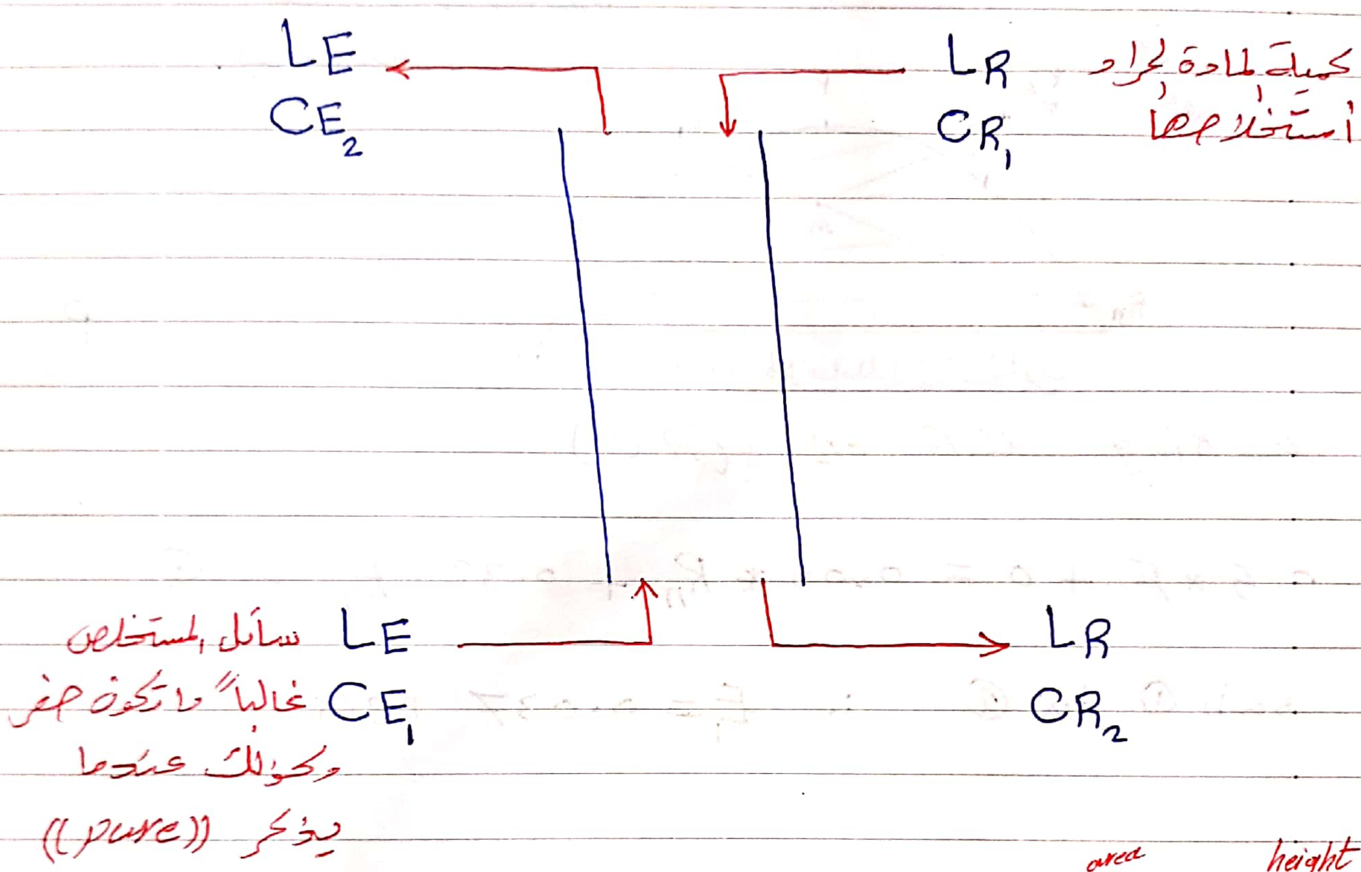
نرسم خط من $(slop_2)$ ليتقاطع نقطة (E_2) من نقطة

$(E_2) \rightarrow (x_2 , y_2)$ نستمر بهذه الطريقة الى أن نصل الى

(x_n) أو بعضها يقول يجب أن لا تتجاوز هذا التركيز.

* continuous extraction in columns :-

((supry , Backed column))



* $L_R (C_{R_1} - C_{R_2}) = \underline{K_R} \, (\Delta C_R)_{Lm} \, \overset{\text{area}}{a} \, . \, \overset{\text{height}}{Z}$

* $L_E (C_{E_2} - C_{E_1}) = K_E \, (\Delta C_E)_{Lm} \, a \, . \, Z$

* $(\Delta C_R)_{Lm} = \dfrac{\Delta C_1 - \Delta C_2}{\ln \dfrac{\Delta C_1}{\Delta C_2}}$ ✓

* $(\Delta C_E)_{Lm} = \dfrac{\Delta C_2 - \Delta C_1}{\ln \dfrac{\Delta C_2}{\Delta C_1}}$ ✓

for ((E)) $\Delta C_1 = CE_1^* - CE_1$

$\Delta C_2 = CE_2^* - CE_2$

for ((R)) $\Delta C_1 = CR_1^* - CR_1$

$\Delta C_2 = CR_2^* - CR_2$

ميل

$CE_1^* = m\, CR_2$ $\qquad CR_2^* = \dfrac{CE_1}{m}$

$CE_2^* = m\, CR_1$ $\qquad CR_1^* = \dfrac{CE_2}{m}$

$$HoR = \frac{L'_R}{KR \cdot a}$$

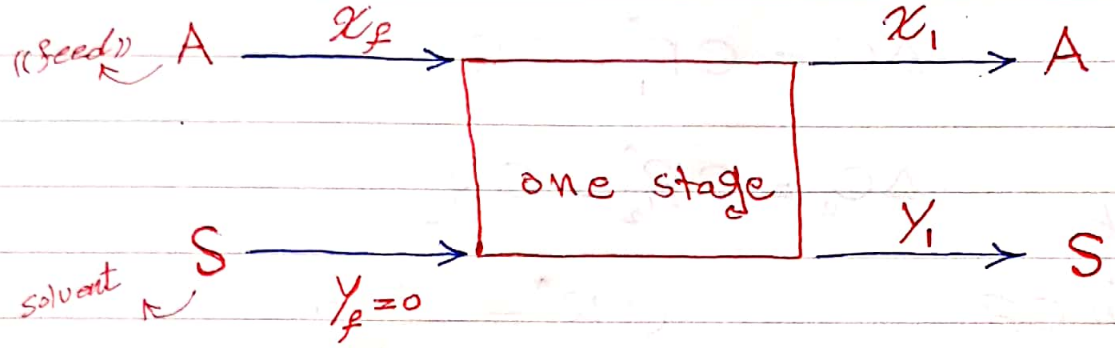
الارتفاع
الكلي بدلالة
Raffinate

$$HoE = \frac{L'_E}{KE \cdot a}$$

الارتفاع
الكلي بدلالة
extract

$$* \quad LR\,(CR_1 - CR_2) = LE\,(CE_2 - CE_1)$$

* co-current - immiscible :-



* اذا اعطى في السؤال عدد المراحل نتبع الخطوات التالية :-

① نستخرج قيمة (x_n) من :-

$$x_n = \left[\frac{A}{A + S\,m}\right]^n * x_f$$

A: mass of solvent

S: mass of solvent added

m: slop

x_f: for solute in solvent

n: number of stage

② نجد x_f من خلال قانون التالي :-

$$x_f = \frac{\text{mass ratio of solute in solvent}}{\text{mass of solvent}}$$

③ نجد ((Final concentration))

$$F.C = \frac{x_n}{1 + x_n}$$

④ نجد ((mass extract))

mass extract = total mass in feed of solute − mass raffinate

* $\boxed{\text{mass raffinate} = x_n * \text{mass of } B}$

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* عندما يطلب في السؤال ايجاد عدد المراحل :- ((n))

* $$\boxed{n = \frac{\log x_n / x_f}{\log \left[\frac{A}{A+Sm} \right]}}$$

أو عن طريق الرسم :-

① نرسم ((eq. curve)) من المعادلة المعطاة في السؤال . (($y = mx$))

② نجد قيمة slop من خلال (($slop = -\frac{A}{S}$))

③ من قيمة slop نجد الزاوية ، ثم نحدد x_f على محور x

ونضع منقلة على ((x_f)) ونحدد الزاوية ثم نمده نحو الكيرف

ومن نقطة التقاء الكيرف وخط الزاوية نحدد x_1 و y_1

* محور x يمثل mass ratio raffinate
* محور y يمثل mass ratio extract

④ نجد $slop_2 = \frac{Y_1}{x_1 - x_f}$ وبنفس الطريقة من

x_1 نحدد الزاوية ونمد خط للكيرف ونجد x_2 و y_2

وهكذا نستمر بهذه الطريقة الى أن نصل الى x_n أو

عندما يذكر أن لا تتجاوز هذا التركيز

101.

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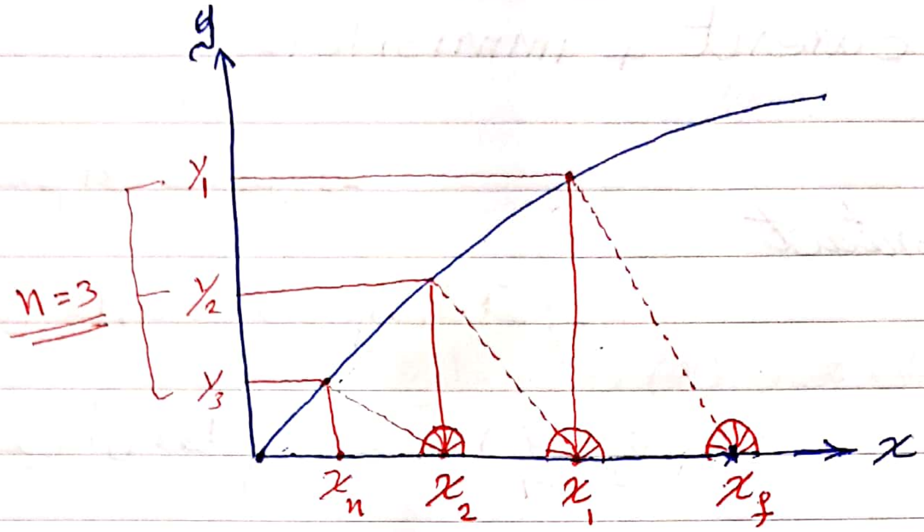
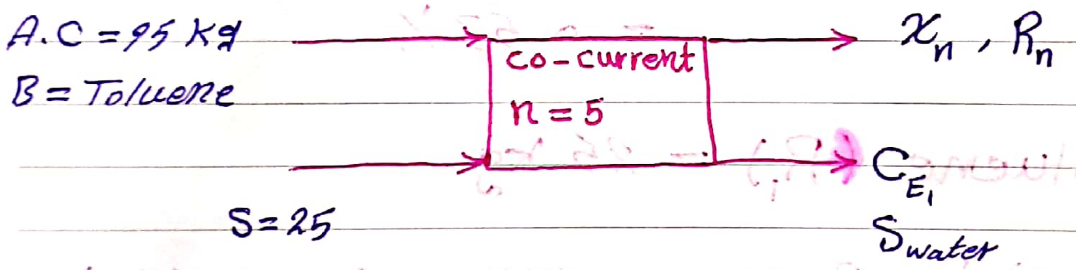


Ex) A cetalaye (5%) is in a solution in toluene is to extrated with water in a five stage co-current unit if 25 kg of water is used 100 kg of feed. find the amount of acetldayde extracted and the final conc.?

$y = 2.2x$

Sol)



$$x_n = \left[\frac{A}{A + m \times S}\right]^n \cdot x_f$$

kg mass solvent = 95 kg ∴ 100 − 95 = 5 kg

kg mass added = 25 kg

$\therefore$ mass ration (A) $= \frac{5}{95} = 0.0527\ x_f$

$$x_n = \left[\frac{95}{95 + 2.2 \times 25}\right]^5 * 0.0527$$

$= 0.00538$ kg / kg solvent

The final conc. $= \frac{0.00538}{1 + 0.00538}$

(قيمة التلوين جا لأنه لا يذوب يعتبر واحد)

$= 0.53\%$

kg Toluene $(R_1) = 25$ kg

$\therefore$ kg (A.C) in R $= 0.00538 \times 95 = 0.511$ kg

$\therefore$ kg extracted $=$ (Total $-$ R)

$= 5 - 0.511$

$= 4.489$ kg

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* counter - curent + immisble :-

ويقسم الى قسمين :-

@ multi - contact

- يمكن الحل بالخطوات التالية :-

① يجب أن نعلم أنه $Top(x_f, y_1)$

$bottom(x_n, y_{n+1})$

② (x_n) اما أن تعطى في السؤال ، أو نفرضها وتكون أقل قيمة في معطيات الكيرف أو أكبر منها بقليل .

③ نجد (x_f) من القانون $x_f = \frac{mass(A)}{mass(B)}$

④ نجد $(slop)$ من خلال $slop = \frac{mass(B)}{mass(S)}$

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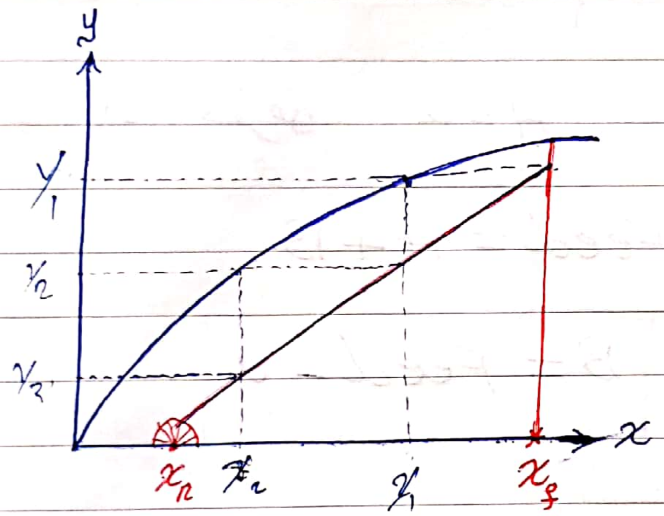
ونبدأ الحل ......

① نرسم (equilibrium data)

② نحدد x_f على محور (x) ونحوده عمودياً الى أن تمس الكيرف.

③ نحدد x_n على محور (x) ونضع عليها المنقلة ومن خلال الزاوية نحسب منها خط يمس x_f



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* بعض الملاحظات المهمة :-

- اذا أعطى (Feed) أو أي معدل بوحدة $\frac{cm^3}{sec}$ ، $\frac{m^3}{sec}$

يجب أن تحول الى $\left(\frac{Kg}{sec}\right)$ وذلك من خلال ضربها بالكثافة.

- عند الحل يجب أن نجد كمية (A) وكمية (B) الموجودة

في (Feed) ، معنى أعطائهم بشكل معدل يشمل كليهما

فيكون :- نفرض $A = d$

$$Feed = A + B$$

$$\boxed{B = Feed - d}$$

- سوف يعطي في السؤال إما ~~كمية~~ نسبة A في Feed أو نسبة

B في Feed نطبق القوانين التالية لاستخراج الكمية

$$A\% = \frac{mass\ A}{mass\ A + mass\ B}$$

$$B\% = \frac{mass\ B}{mass\ A + mass\ B}$$

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EX) 160 cm^3/s of a solvent (S) is used to treat 400 cm^3/s of a 10 per cent by mass solution of A in B, in a three-stage countercurrent multiple-contact liquid-liquid extration plant. What is the composition of the final raff.

- using the same total amount of solvent, evenly distributed between the three stages. what would be the composition of the final raffinate if the equipment were used in a simple multiple-contact arrangement?

بالتساوي توزع

eqm. Data

(x) Kg A/kg B:	0.05	0.10	0.15
(y) Kg A/kg S:	0.069	0.159	0.258

Densities (Kg/m³): $\rho_A = 1200$, $\rho_B = 1000$, $\rho_S = 800$

Sol)

$$S = 160 \frac{cm^3}{s} \left| \frac{1 m^3}{(100)^3 cm^3} \right| \frac{800\ kg}{m^3} = 0.128 \frac{kg}{s}$$

$$A = \alpha \Rightarrow A = 1200\,\alpha$$

$$B = Feed - \alpha$$
$$= (4 \times 10^{-4} - \alpha) \times 1000$$
$$= 0.4 - 1000\,\alpha$$

sema NOTEBOOK & STATIONERY

$$0.1 = \frac{1200d}{1200d + 0.4 - 1000d}$$

$$0.1 = \frac{1200d}{0.4 + 200d}$$

$$0.04 + 20d = 1200d$$

$$d = 3.39 \times 10^{-5}\ m^3/s$$

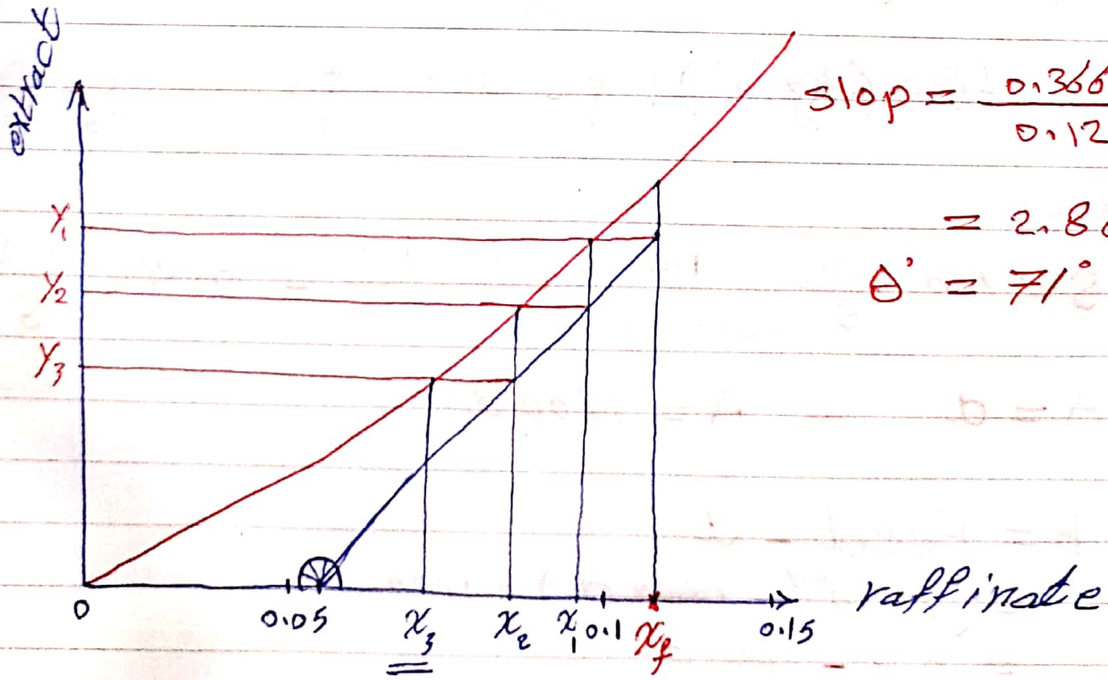
$$A = 1200 \times d$$

$$= 0.041\ \frac{kg}{s}$$

$$B = 0.4 - 1000 \times d = 0.366\ \frac{kg}{s}$$

$$x_f = \frac{0.041}{0.366} = 0.112$$

$$x_n = 0.057$$



$$slop = \frac{0.366}{0.128}$$

$$= 2.86$$

$$\theta' = 71^\circ$$

* composition of final raffinate = 0.057

$$S = \frac{0.128}{3} = 0.0427$$

$$x_f = \frac{0.041}{0.366} = 0.112$$

منه نحسب

stage 1 ⇒ $Y_1 = 0.18$

$$E_1 = Y_1 \times S = 0.18 \times 0.0427 = 0.0077$$

$$R_1 = A - E_1 = 0.041 - 0.0077 = 0.0333$$

$$B = 0.366$$

$$x_1 = \frac{0.0333}{0.366} = 0.091$$

نحددة على محور (x) ونمده للكيرف "عمودياً" ونحسب y_2

stage 2 ⇒ $Y_2 = 0.14$

$$E_2 = 0.14 \times 0.0427 = 0.006$$

$$R_2 = 0.0333 - 0.006 = 0.0273$$

$$B_2 = 0.366$$

$$x_2 = \frac{0.0273}{0.366} = 0.075$$

نحددة على محور (x) ونمده "عمودياً" للكيرف ونحسب y_3

stage 3 ⇒ $Y_3 = 0.114$

$$E_3 = 0.114 \times 0.0427 = 0.0049 \text{ kg/s}$$

$$R_3 = 0.0273 - 0.0049 = 0.0224$$

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$B = 0.366 \ kg/s$

$x_3 = \frac{0.0224}{0.366} = 0.061$

$\therefore$ composition of final raffinate

$= 0.061 \frac{kg\ A}{kg\ B}$

* countercurrent contact with partially miscible solvents.

* اذا اعطي في السؤال نسب وزنية فيجب الحل بطريقة المثلث لايجاد عدد المراحل :-

① نرسم معلومات التوازن بطريقة المثلث لرسم منحني التوازن بين (Raffinate ، extract)

② نحدد خطوط الربط (tie line) بين (Raffinate , extract)

③ من معلومات السؤال أجد النقطة (M) وذلك حسب تطبيق قاعدة (lever arm Rule)

④ نحدد نقطة (Feed) من معلومات السؤال

⑤ نرسم خط بين (Feed) وآخر قيمة للمستخلص

⑥ نمد خط من (R_n) الى آخر قيمة للمستخلص ويمتد ليلتقي بنقطة (P)

⑦ من R_n الى M نمد خط ليلتقي بنقطة E_1

⑧ من Feed الى E_1 نمد خط ليلتقي بنقطة (P) خارج المثلث.

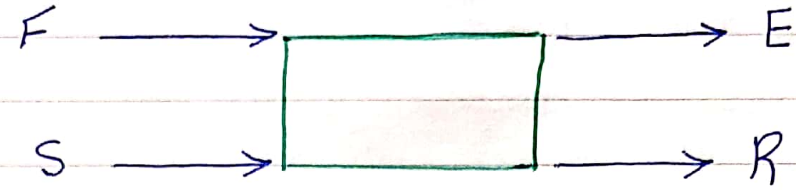
⑨ من E_1 نمد خط موازي للـ tie line ليلتقي بمنحني الـ Raffinate بـ R_1

⑩ من R_1 نمد خط الى (P)، ونقطة التقاء الخط مع منحني extract تسمى E_2

⑪ من E_2 نمد خط موازي للـ tie line ليلتقي بمنحني الـ Raffinate د R_2

⑫ من R_2 نمد خط الى (P)، ونقطة التقاء الخط مع منحني extract تسمى E_3

⑬ ونستمر بهذه الخطوات الى أن نصل الى أخر قيمة د Raffinate وهي R_n، ومن قيم (R) نحسب عدد المراحل.



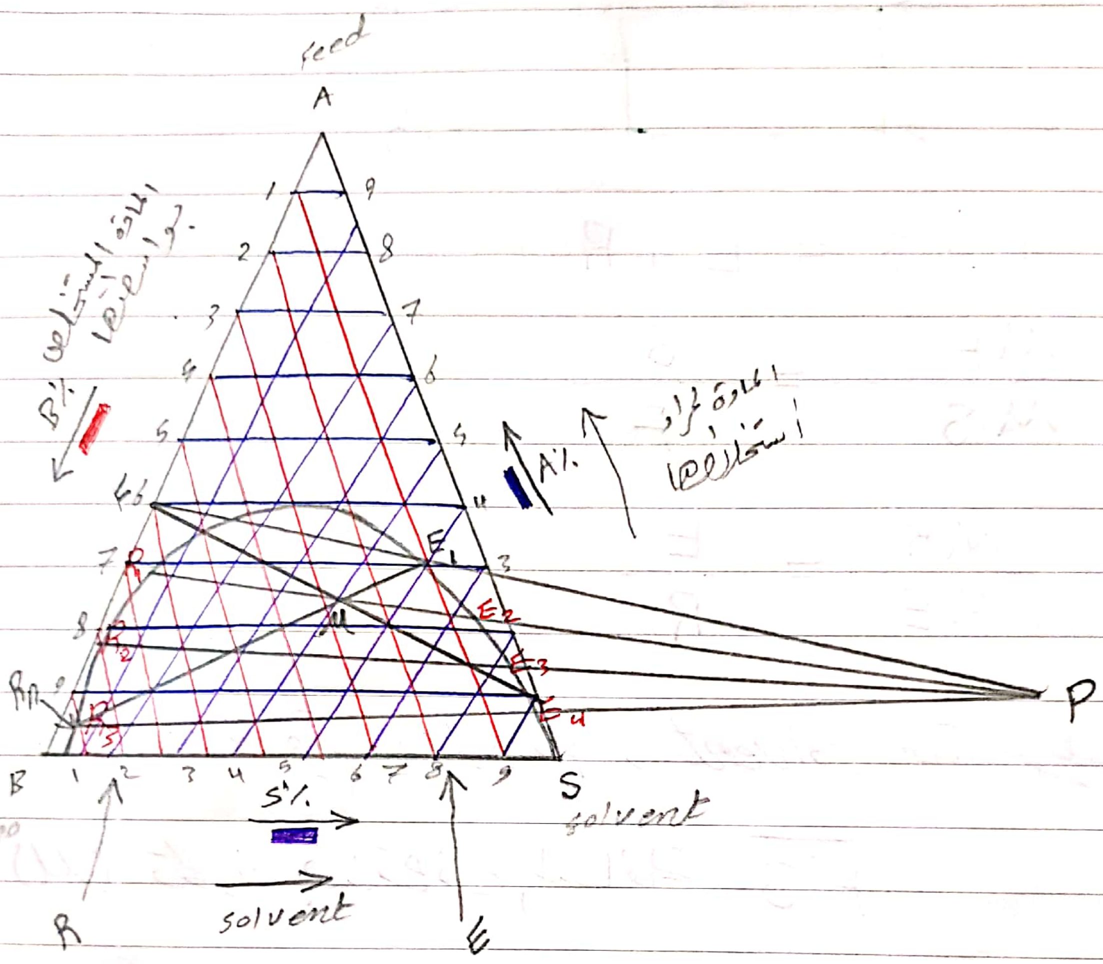
$$F + S = E + R$$

$$\frac{MF}{MS} = \frac{S}{F} \longrightarrow \text{min , Max}$$

min ← MS
Max

$$\frac{MR}{ME} = \frac{E}{R}$$

* اذا كانت قيم ال Feed ، solvent متساوية فان نقطة
(M) تكون بمنتصف المسافة $\overline{FS}$


feed
A
B
S
B%
A%
S%
solvent
solvent
R
E
P
M
E1
E2
E3
E4
R1
R2
R3
Rn

Example 3: Single Step Extraction

The basic mixture of 100 kg exists of 40 mole% acetone and 60 mole% water and has to be extracted with trichloroethane, which is preloaded with 15 mole% acetone.

يجب استخلاصه

الذي تم تحميلها مسبقاً مع

Your have to determine:

a) the phase diagram of the system acetone / water / trichloroethane in the triangle diagram.

b) the minimum and maximum amount of solvent,

c) the necessary amount of solvent, if the raffinate contains 4,82 mole% acetone,

d) the amount and composition of the produced raffinate and extract,

e) the extraction process in the triangle diagram

Phase equilibria data for the system water / acetone / trichloroethane

phase equilibria data for the coexisting phases in mole%					
extract phase			raffinate phase		
trichloroethane	acetone	water	trichloroethane	acetone	water
80,18	أكبر 17,7	2,	0,07	أقل 1,9	97,9
59,01	35,9	5,	0,10	4,8	95,0
49,17	44,0	6,	0,12	6,8	93,0
35,99	53,7	10,2	0,17	10,3	89,4
25,04	58,3	16,6	0,29	14,9	84,7
14,56	56,9	28,4	0,78	21,9	77,2
9,94	52,4	37,5	1,50	27,3	71,1

$$FS = MF + MS$$

$$78\,mm = MF + MS$$

$$MS = 78 - MF$$

$$\frac{MF}{MS} = \frac{S}{F} \Rightarrow \frac{MF}{91.5\ \cancel{78} - MF} = \frac{95}{100}$$

$$100\,MF = \cancel{\ldots} - 95\,MF$$

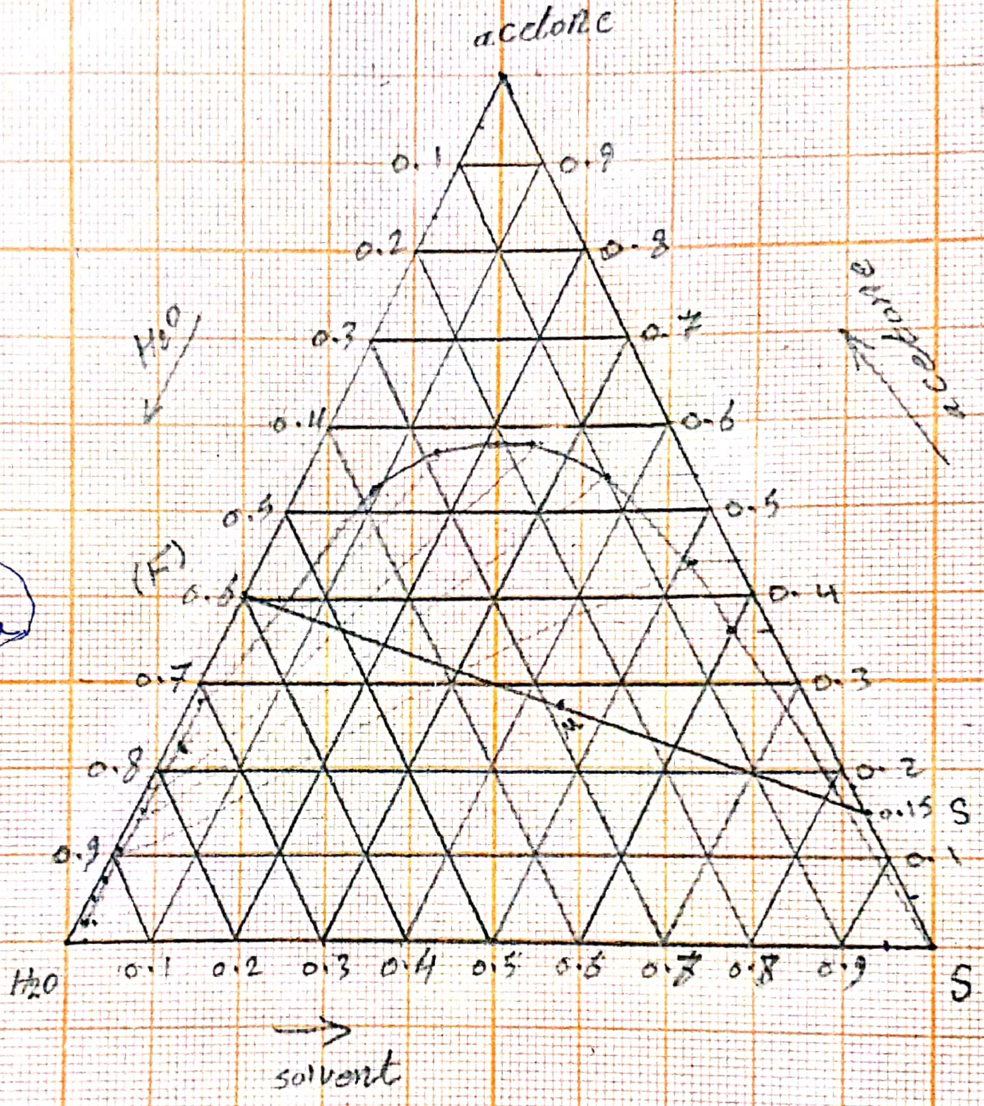
$$195\,MF = \cancel{\ldots}\ \cancel{\ldots}\ 8692.5$$

46

$$MF = 38$$

Example (3)

$\overline{FM}_{mix}$



$\overline{FS} = 78\ mm$

$$\frac{\overline{FM}}{\overline{SM}} = \frac{S}{F}$$

Example 5: Multi Step Countercurrent Extraction

The acetic acid / water mixture of Is extracted 2 kg/~~h~~s in a multi step countercurrent extraction cascade with isopropyl ether as solvent. The residual acetic acid concentration is also given with 10 wt%.

Rn Rn

$F = 2$ kg/hr

$S = 2.649$ kg/hr

$R_n = 10\%$

$x_f = 0.45$

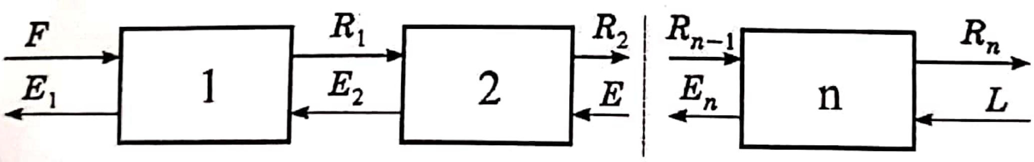
You have to determine:

a) the necessary amount of theoretical extraction steps in the triangle diagram for the case that the effective amount of solvent is 2649 kg/h.

2.649 kg/h

Phase equilibria data

extract phase			raffinate phase		
acetic acid	water	isopropyl ether	acetic acid	water	isopropyl ether
0,002	0,005	0,993	0,007	0,981	0,012
0,004	0,007	0,989	0,014	0,971	0,015
0,008	0,008	0,984	0,029	0,955	0,016
0,019	0,010	0,971	0,064	0,917	0,019
0,048	0,019	0,933	0,133	0,844	0,023
0,114	0,039	0,847	0,255	0,711	0,034
0,216	0,069	0,715	0,367	0,589	0,044
0,311	0,108	0,581	0,443	0,451	0,106
0,362	0,151	0,487	0,464	0,371	0,165

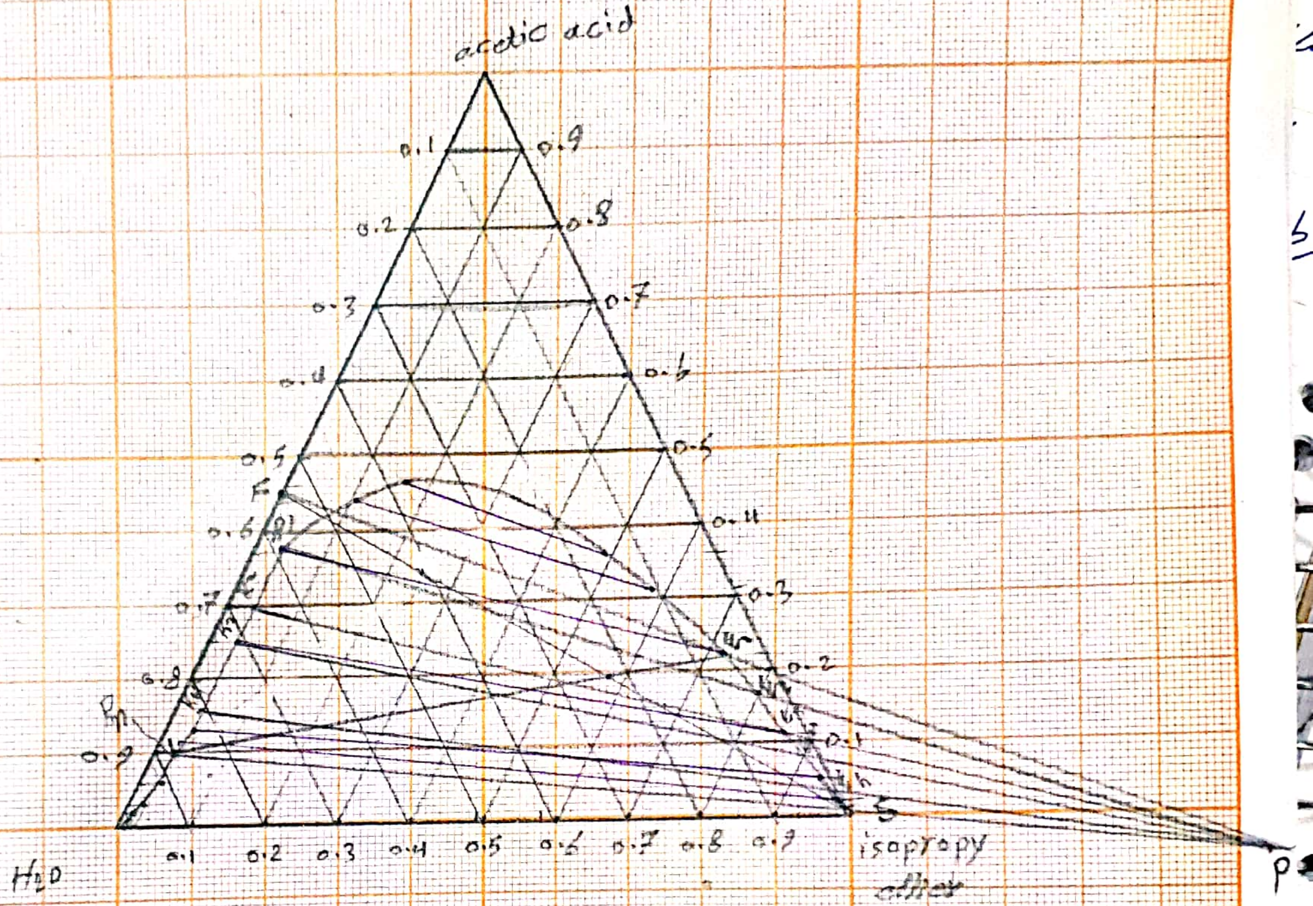


reduce
requal
remain
residual

R_n

$2649 \times \frac{1\,h}{3600\,s}$

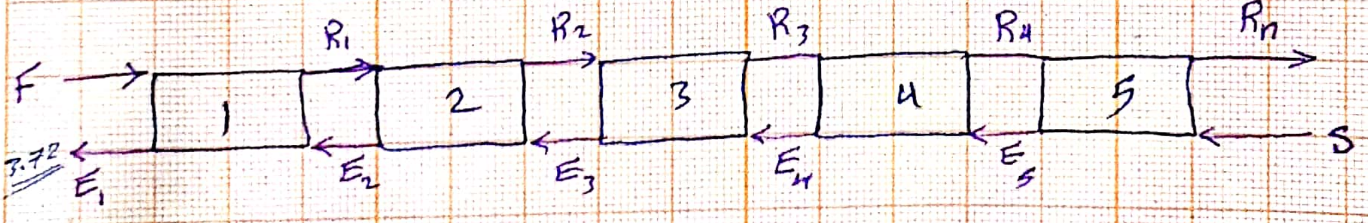
Example (5)



$\overline{FS} = 90\ mm$

$\overline{FM} = 52\ mm$

$\overline{SM} = 38\ mm$



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propelm(1) Acetic acid and water mixure excepled in multi stage counter current extraction using iso proply ether as solvent. The resqual acetic acid concentration (10%) by wieght. what is the amount and compostion extract and Raffinat for each stage. if: the Maximum compostion of acetic acid (0.291) equilibrium data J.K: and the effective of solvent is (2.649) Kg/hr. the feed contain (2 Kg/hr), $x_f = 0.45$ of acetic acid.

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⊛ Leaching process :-

$$C = C_s \left[1 - e^{-\frac{K_L \cdot A}{V} t} \right]$$

* مجرد ما أشوف كلمة (saturated) أعرفها (C_s)
تعني (أكبر تحميل يكون المذيب حملها)

t :- الزمن

V :- حجم الخزان اللي يصير به الغسل

c :- تركيز المذاب في أي زمن

$$\theta_N = \frac{1}{(1+\beta)^n}$$

$$N = \frac{\log\left(\frac{1}{\theta}\right)}{\log(1+\beta)}$$

$$\theta_N = \frac{\text{تركيز المادة المذابة المتبقية في المذيب في المرحلة الأولى}}{\text{تركيز المادة المذابة المتبقية في المذيب في المرحلة النهائية}}$$

$$\theta_N = \frac{S_N}{S}$$

$$B = \frac{b}{a} \qquad \frac{\text{كمية المذيب المسكوب}}{\text{كمية المذيب المضاف}}$$

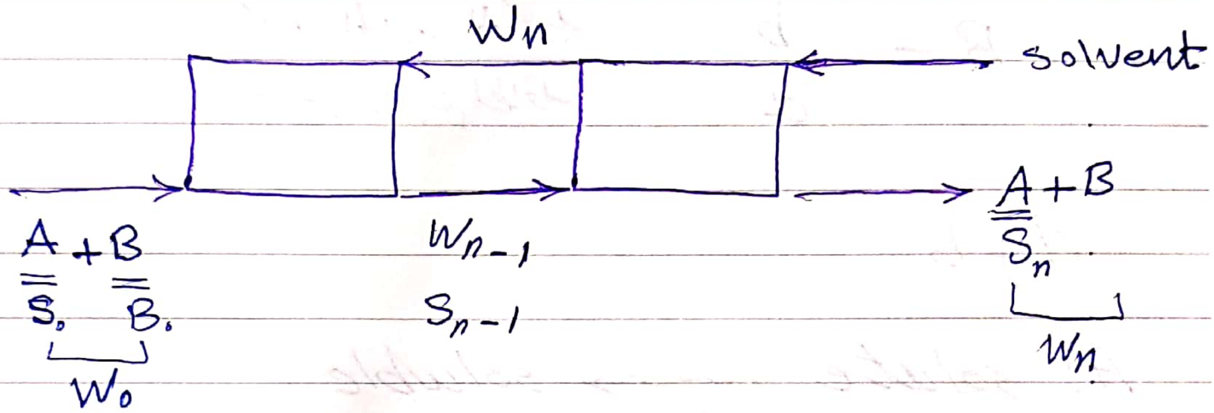
$A + B$

A: solute ⟶ soluble
B: in soluble
S: solvent (المادة التي أضيفها)

$$x_A = \frac{S_N}{B + S_N}$$

⊛ contiouns leching

① constant under flow.



$$R = \frac{\text{تدفق المذيب في الجزء العلوي (over flow)}}{\text{تدفق المذيب في الجزء السفلي (under flow)}}$$

$$F = \frac{S_n}{S_0} = \frac{(R-1)}{(R^{n+1}-1)}$$

F = Fractional of solute discharge

$$F = (1-\eta)$$

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* اذا عندي محلول وأريد أطلع كمية الـ(solute)

$$\boxed{\text{solution} = \text{solute} + \text{solvent}}$$

$$N = \frac{\log\left[1 + \frac{R-1}{f}\right]}{\log(R)} - 1$$

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Ex)

1.6 Kg/s of sand-salt mixture containing 62.5% sand is leached with 0.5 kg/s of water in a countercurrent. The residue from each stage containing 0.25 Kg water per Kg insoluble solid. Find the number of stage such that the sand from the final stage contains 10% salt when dried.

$F = 1.6$ kg/s

A: solute, soluble, salt

B: insulable, sand

$B = 1.6 \times 0.625 = 1$ kg/s

A or $S_0 = 1.6 - 1 = 0.6$ kg/s

$$0.1 = \frac{S_n}{B + S_n}$$

$$0.1 = \frac{S_n}{1 + S_n} \Rightarrow S_n = 0.11 \text{ kg/s}$$

$$F = \frac{S_N}{S_0} = \frac{0.11}{0.6} = 0.183$$

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$$R = \frac{\text{solvent over flow}}{\text{solvent under flow}}$$

$$0.25 = \frac{Kg\ H_2O}{Kg\ B}$$

solvent under $= 0.25 \times B$

$= 0.25 \times 1 = 0.25$

$$R = \frac{0.5}{0.25} = 2$$

$$N = \frac{\log\left[1 + \frac{R-1}{F}\right]}{\log(R)} - 1$$

$$= \frac{\log\left[1 + \frac{2-1}{0.183}\right]}{\log(2)} - 1$$

$= 1.69$

الشرح بالملزمة

منتظر صلاح

الامتصاص

* Absorption :- is one of physical separation process where one component of gas mixture will absorb by aliquid solvent from agas phase to aliquid phase.

- هو واحد من عمليات الفصل الفيزيائية حيث مركب واحد من خليط الغاز سوف يفصل بواسطة مذيب سائل من الطور الغازي الى الطور السائل.

الانتزاع

* Stripping :- is a unit operation where one or more components of aliquid stream are removed by being placed in contact with agas stream that is insoluble in the liquid stream.

وهو وحدة تشغيلية حيث مركب او اكثر من مجرى السائل سيزال بواسطة بدأ مكان في الاتصال مع مجرى الغازي ويكون غير مذاب في مجرى السائل.

* Absorber and strippers are often used :-

مع

1- in conjuncation with each other
2- Absorbers are used to removed trace component from gas stream.
3- strippers are used to removed trace component from liquid stream.

4- carried out in vertical and cylindrical column or tower contains plates or packing elements.

* two types of tower absorb:

1- tray tower
2- pack tower

* Design of an absorber requires consideration a number of factors, including:

1- entering liquid flow rate, Temp., ~~component~~, composition and pressure which are generally set from the proceeding unit operation.
2- Desired degree of recovery of one or more solute which it is generally set by Designer.
3- choice the absorbent where as the ideal adsorbent.
4- operating pressure and temp.
5- minimum absorbent flow rate.
6- number of equilibrium stages.
7- Height of absorber.

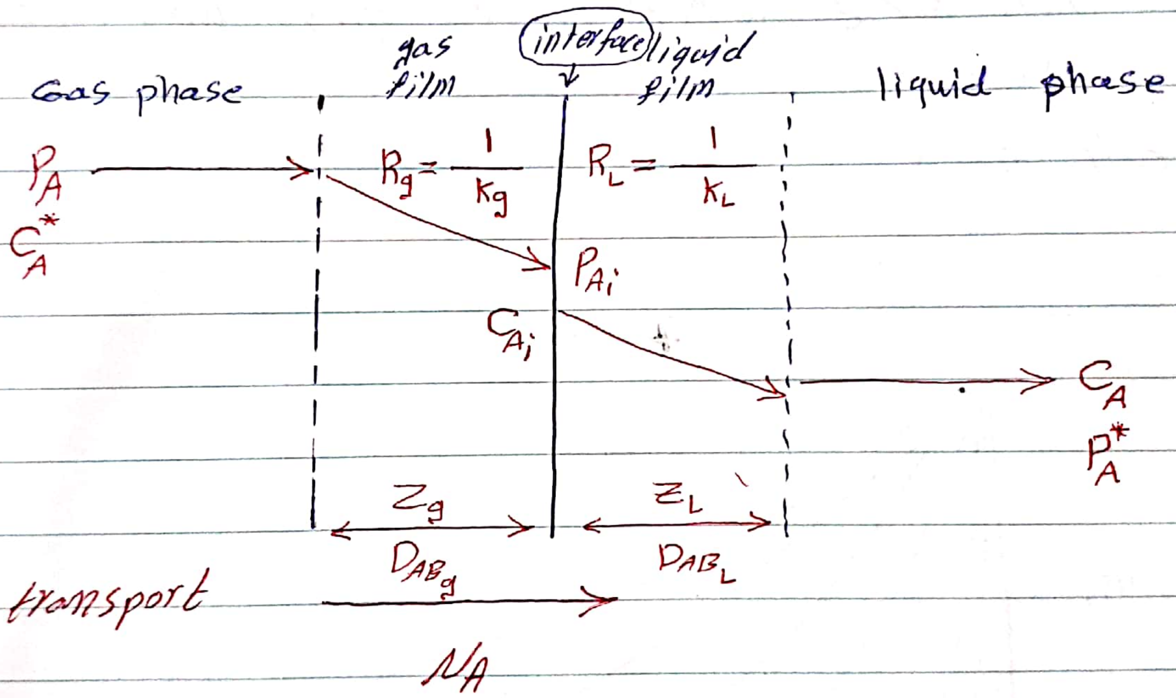
a) bubble-cap tray
b) ~~sette~~ sieve tray
c) bubble tray

plate types

* Mass transfer theories:-

1- The Two-Film theory:

- the Two-film theory of whitman (1923) was ~~a~~ the first serious attempt to ~~[illegible]~~ represent condition occurring when material is transferred in a steady state process from one fluid stream to ~~another~~ another.



نظرية الاختراق

2- The penetration theory :-

في اقتراحها تم

The penetration theory was suggested in (1935)

فيما اذا يحقق كان الذي بواسطة

by Higbie who was investigating whether

في كانت مقاومة النقل موجودة أم لا

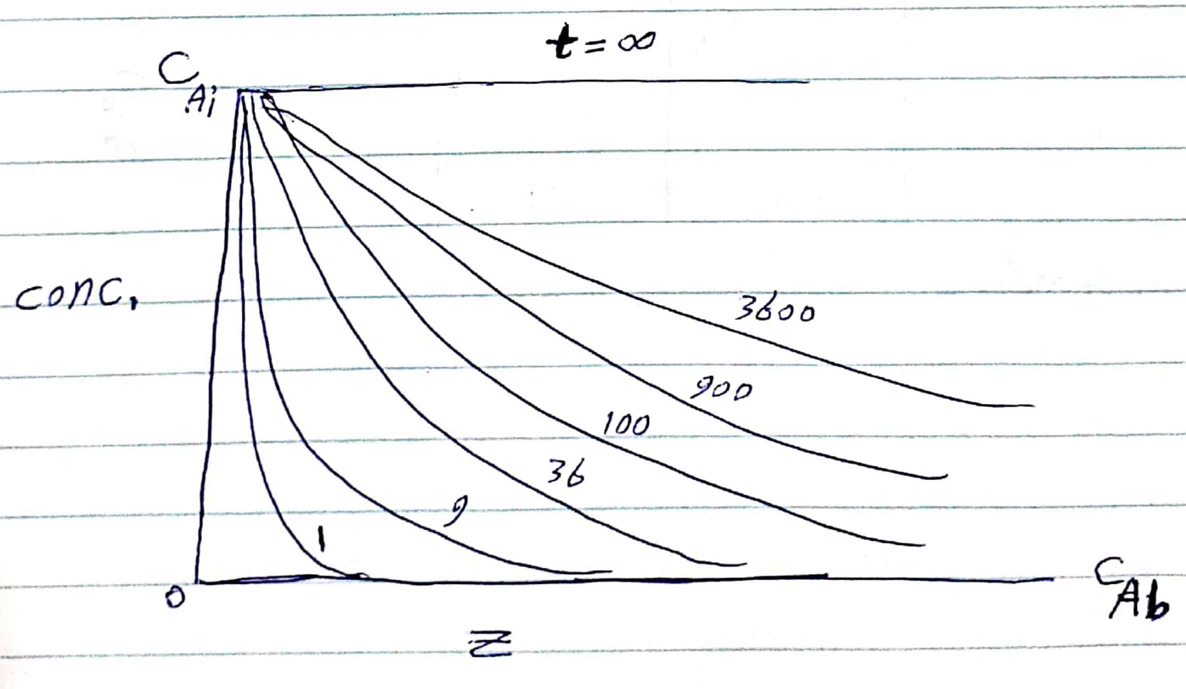
or not a resistance to transfer existed at

يتم امتصاص غاز نقي عندما الواجهة

the interface when a pure gas was absorbed

السائل في

in a liquid.



3- Film theory :-

نموذجاً نظرياً بسيطاً

- A simple theoretical model for

من أو إلى لنقل الكتلة المضطرب

turbulent mass transfer to or from

اقترح حدود الطور السائل

a fluid-phase boundary was suggested

افترض والذي نيرنست عام في

in 1904 by Nernst, who postulated

الكتلة المقاومة الكاملة أن

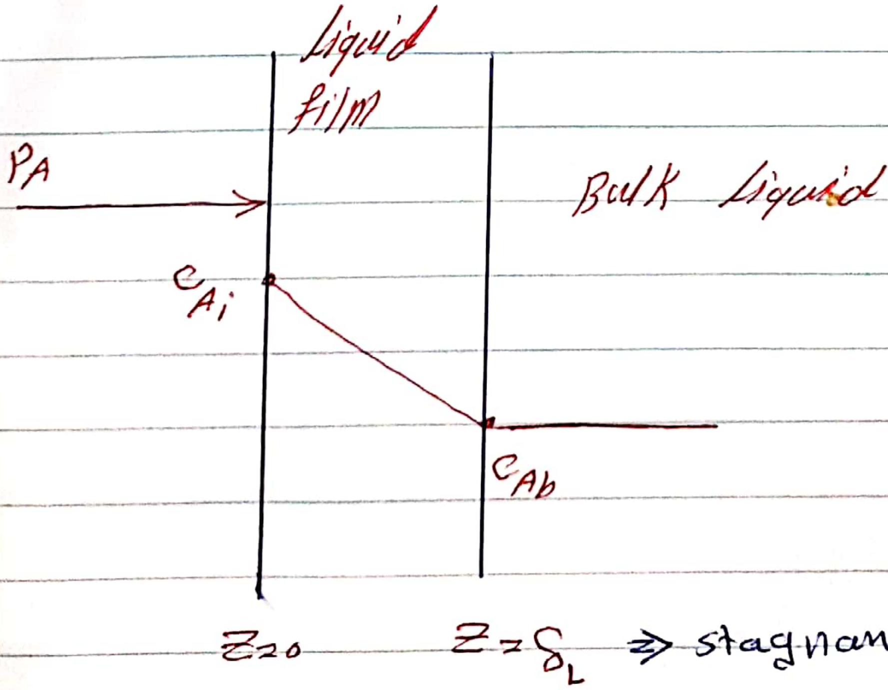
that the entire resistance to mass

تكون مضطربة مرحلة في لنقل

transfer in a given turbulent phase

رقيقة

is in a thin.



$\Rightarrow$ stagnant liquid film of thickness.

Summery

الغاز من بشكل من مركب أكثر أو واحد لامتصاص انتقائي

1. A liquid can be used to selectively absorb one or more components from a gas mixture. A gas can be used to selectively desorb or strip one or more components from a liquid mixture.

المعاكس في انتزاع أو امتصاص يمكن أن يحكى الذي المركب من جزء

عامل الامتصاص ② و المراحل المتوازنة عدد ①

يعتمد

2. The fraction of a component that can be absorbed or stripped in a countercurrent depends on the number of equilibrium stages and the absorption factor.

مزودة الصواني أبراج في معظمها عادة أجراء يتم الانتزاع و الامتصاص

تعبئات مهيكلة أو عشوائية معبأة أبراج في أو صمامات أو غربال

3. Absorption and stripping are most commonly conducted in trayed towers equipped with sieve or valve trays, or in towers packed with random or structured packing.

① ②

تشغيلها فعالية أكثر هي

4. Absorbers are most effectively operated at high pressure and low temperature. The reverse is true for stripping. However, high costs of gas compression, refrigeration. and vacuum often preclude operation at the most thermodynamically favorable conditions.

حسابها نستطيع للمحاليل المخففة الانتزاع أو للامتصاص معدل التدفق العامل

الرسم باستعمال خط التشغيل و خط الاتزان من

5. The number of equilibrium stages required for a selected absorbent or stripping agent flow rate for the absorption or stripping of a dilute solution can be determined from the equilibrium line, and an operating line, using graphical. Algebraic, or Numerical methods. Graphical methods,

6. Packed column height can be estimated using the HTU/NTU concepts, with the latter having a more fundamental theoretical basis in the two-film theory of mass transfer.

أبراج الحشوات في كبيرة ميزة واحدة

7. One significant advantage of a packed column is its relatively low pressure drop per unit of packed height, as compared to a trayed .